FINAL REPORT

END PRODUCT QUALITY ASSESSMENT SYSTEMS FOR FLAKED AND FORMED STEAKS

PREPARED FOR THE

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OVERALL SUMMARY AND CONCLUSIONS

Flake Size

Flake size was the factor among all those studied in this report that had the greatest influence on textural properties. A texture profile panel was thus developed using steaks manufactured from various Comitrol heads. In three separate studies, this panel found steaks made from large flakes to be possessive of more fibrousness, greater first bite hardness, less first bite uniformity, less complete and incomplete shearing after two bites, more cohesiveness of mass, less uniformity of mass and greater amounts of detectable connective tissue than steaks processed with smaller flake size heads. The use of smaller flake size particles did in some cases reduce the standard deviations of textural properties, but the textural properties of small particle steaks (060) do not closely resemble those of intact muscle steak. The 1628 head may be the Comitrol head of choice for producing steak-like texture, but yet reducing detectable connective tissue. Instron values showed tremendous steak to steak and within steak variation for steaks from the same batches. Often the range in variation within steaks would encompass values obtainable over two-thirds of the range in Comitrol head size. With the presence of this much variation in such factors as connective tissue, muscle hardness, adhesion, etc., it is doubtful that meaningful end product texture separating procedures can ever be attained. Surprisingly, an evaluation of Comitrol head sizes or flaked and formed pork steaks did not greatly reduce this variability.

Processing Variables

An evaluation of various fat levels (10, 14, 18, 22%) indicated that increased levels of fat resulted in increased detectable connective tissue, juiciness and mouthcoating. Other than a slight reduction in Instron Newton values as fat went up, other textural properties were not greatly affected by fat level.

With restructured steaks processed from USDA Choice Yield Grade 2 and 3 chuck meat, blade tenderization (up to 12X) reduced shear force values, but did not greatly influence other textural properties.

A comparison of four flaking temperatures (28°, 34°, 40° and 40° reduced to 34° with dry ice at the time of flaking) and three mixing times of 4, 8 and 16 min failed to generate many differences in textural and cooking properties. Increased blending times resulted in less steak diameter shrinkage during cooking.

The use of prerigor pressurization was used on Utility cow round and chuck muscles with little effect being noted on texture and cooking properties. Steaks made from round muscle were less uniform in texture, had more detectable connective tissue, had less shearing during chewing and higher shear force values than steaks manufactured from chuck muscles. Chunked and formed steaks made from the pressurized beef were rated as harder, more cohesive, less uniform and possessive of more connective tissue than flaked and formed steaks. Increased salt usage (0.00, 0.25, 0.50%) resulted in substantially higher Instron values. Thus, it would appear that the processing variables in this study either did not affect texture or were undetectable due to within product variation.

Connective Tissue Effects

Connective tissue differences were identified early in this project as a possible cause of end-product variation. Using the same team of boners and trimmers, it was shown that some day to day variation could exist in the connective tissue levels found in restructured steaks as measured by collagen values. A study comparing various intensities of trimming for connective tissue showed that removal (or addition) of connective tissue could greatly influence textural properties. As a result of this, a large consumer study was undertaken to determine if consumers could detect designed differences in connective tissue (gristle) and was it important in an item such as restructured steak.

While considerable attempts were made to have broad differences in connective tissue levels in steaks, the differences were probably not large enough to be accurately perceived by all consumers. Steaks made to have low levels of gristle had some problems with flavor and appearance and thus made their acceptability no better than steaks with extra high levels of connective tissue. Consumers seem to have broadly differing opinions on what gristle is in these types of products and often confuse it with texture in general. Consumers who consider gristle as a major undesirable characteristic in beef seem to be better able to logically separate steaks on the basis of gristle. The results of this consumer study, to some degree, question the importance that should be given to reducing or eliminating the effects of connective tissue in restructured steaks.

Cooking Procedures

Variations in cooking methods were seen as a possible cause leading

to the variation in textural properties of these steaks. Since distortion (alternating swelling and shrinking) and excessive crust formation were frequently observed, slow water bath cooking (sealed cooking bags) was evaluated. Considerable reduction in the variability of shear force values was noted regardless of final cooked meat temperature. While higher internal temperatures resulted in higher cooking losses, the constant shear values were probably obtained due to the absence of crust formation. In later tests with Comitrol 060 steaks, samples often could be almost completely compressed before crust rupture would occur.

Since the texture panel's charge was to determine textural parameters of possible consideration for Instron measurement, the effects of sample temperature (hot for panel, room temperature for Instron), had to be determined. Textural properties (sensory and instrumental) were not affected by the two serving temperatures.

Distortion of steaks during cooking, in our opinion, is a major factor influencing textural properties in flaked and formed steaks. As a means of controlling this problem, a study was undertaken using flat 557 g weights on the steaks during cooking with procedures to alter air movement over the steaks during cooking. The use of these two procedures was basically ineffective in reducing distortion and variability in textural parameters.

Attempts to alter the surface of steaks during cooking to reduce distortion were also employed. This consisted of spike penetration during cooking (to release steam, juices) and lined indentations. With the exception of a few textural changes as a result of spiking, these two techniques proved unsuccessful for reducing "macro" distortion.

Instron Measurements With Promise

Obviously, the variability in textural properties and the inability to control or reduce them has led to difficulties in establishing quick and accurate instrumental tests for use in making product purchase decisions. Due to the differences apparent in steaks of different head sizes in "layering" (sideways separation when pressure is placed on the crust surface) adhesion tests have been tried and may have some promise. Change in stress in relation to change in strain (modulus of elasticity) demonstrates sample resistance and relates to first bite cohesiveness (and perhaps also crust formation). This procedure also may be useful where crust thickness differences exist. Repeated compression measurements on the same sample may show differences in bind strength. Differences in percent fail energy (load at 80% of peak load) may be useful in characterizing the total influence of crust, "tough" muscle pieces and connective tissue on texture.

GENERAL INTRODUCTION

Steak meat has been and continues to be the most consumer desired and thus expensive item from the beef carcass. Unfortunately, only a certain volume of "high quality" muscles exist on the carcass for steaks. The meat industry in an attempt to increase the volume of steak or steak-type products has utilized processing techniques in an attempt to "add value" to lower priced muscles and cuts by processing them into "restructured" or "intermediate value" products. The term "intermediate value" infers that the value of the product is between that of steak and ground beef. Many people have difficulty with this terminology and definition, feeling that the procedures and technology used to produce a restructured product has or should create a "value added" product close to that of intact muscle. It was the original intent of the Military Services that restructured products have a solid muscle-like texture and thus be used as a possible replacement of solid muscle steaks. However, early work by the U.S. Army Natick Laboratories and subsequent efforts reported in this study indicate that with present "flaked and formed" procedures, the textural properties are indeed intermediate to those found in ground beef and intact muscle steaks. Perhaps chunked and formed procedures are more capable of producing a steak-like texture than flaked and formed techniques.

In order to obtain the steak-like texture and associated uniformity that is inherent in high quality intact muscle steaks, the Military, through USDA purchase specifications, imposes requirements that only certain grades, parts and proportions of carcasses be used in formulations. This type of product quality control is permissable and

desirable, however, USDA and Military agencies cannot require that certain technology (equipment) be used if these techniques give an advantage to certain segments of the industry. If it were feasible to evaluate the end product in objective terms of quality, it would not be necessary to specify formulations, techniques, etc. If the vendor could produce a wholesome, high-quality, uniform product, then the raw materials or technology used should be of no concern to the buyer or end user. If industry could duplicate the texture of the flaked steak, using other types of equipment, then that should be suitable to the military and USDA. However, in order for industry to duplicate any product they must have end-product specifications.

Therefore, the objective of this study was to develop human sensory and/or instrumental methods for assessing texture of flaked and formed steaks that could be used in purchase specifications and quality assessment decisions.

EFFECTS OF FLAKE SIZE ON SENSORY, CONSUMER, SHEAR AND COOKING PROPERTIES OF RESTRUCTURED BEEF STEAKS

Introduction

Many processing systems exist for producing beef in a multiple of shapes and particle sizes for restructured products. In the case of both beef and chicken, the use of smaller flake size meat has resulted in higher tenderness scores (Durland, et al., 1982; Seideman, et al., 1982ab). A consumer study with restructured beef steaks processed from a wide variety of Comitrol heads indicated that maximal acceptability was found for the intermediate flake sizes (Cardello, et al., 1983). With pork, larger flake sizes have resulted in higher sensory scores when the raw material was flaked at 2.2 C. No differences were found in sensory attributes when a flaking temperature of -5.6 C was employed (Popenhagen, et al., 1973). Costello, et al. (1981) reported that fiber orientation during flaking may play an important role on subsequent sensory evaluation of restructured beef steaks.

This first initial study was a follow-up to an original study (Cardello, et al., 1983) at Natick Laboratories using these same Comitrol head sizes and a consumer acceptance panel. It provided information to the Meat Science Research Laboratory on the amount and type of variation in sensory attributes that could be expected with this product.

Materials and Methods

Steaks for this study and most of the following studies were manufactured at the U.S. Army Natick Research and Development Laboratories. All steaks were made from USDA Choice, yield grade 2 or 3, square-cut chucks that had been boned and trimmed of fat to 18 $\pm$ 2%. The

boneless meat was tempered to 0° C and flake cut with an Urschel Comitrol, Model 3600 (Urschel Laboratories, Inc., Valparaiso, IN 46383) using one of several specified cutting heads. The meat was mixed eight minutes in a ribbon-type mixer (Keebler, Chicago, IL 60636) under vacuum with salt (NaCl) and sodium tripolyphosphate ($Na_5P_3O_{10}$). The levels of salt and sodium tripolyphosphate were 0.5% NaCl and 0.25% $Na_5P_3O_{10}$. The meat was stuffed into polyethylene tubing (lay-flat dimension = 13.3 cm) under vacuum (Vemeg Robot 100 S2 Type 116, Robert Pfiser and Co., Inc., Boston, MA 02210) clipped and pre-shaped to approximate the die shape. The meat log (2.7 - 3.6 kg) was frozen to -18° C and tempered to -3° C. The meat was then pressed at 8.75×10^4 N/m^2 in die #452 (Ribeye) using a Bettcher press, Model #70 Bettcher Industries, Inc., Vermillion, OH 44089). The formed log was sliced on a Bettcher cleaver, Model #39 (Bettcher Industries, Inc., Vermillion, OH 44089) to produce a 6 oz. steak. The steaks were separated with patty paper, placed in sealed polyethylene bags, frozen immediately to -18° C and stored at -18° C until time of testing.

Restructured steaks were broiled on open hearth Farberware broilers for descriptive attribute panel and Instron testing. The steaks were cooked on one side for 12 min, turned and then cooked on the other side to an internal temperature of 68.3 C. For the consumer tests, steaks were cooked on Black Angus electric griddles (163 C), turning every four min until an internal tmeperature of 68.3 C was achieved.

Samples (2.54 cm^2) were served immediately after broiling to a ten-member descriptive attribute panel who scored the samples for the attributes identified and defined in Table 1. A 25-member consumer panel evaluated the samples immediately after grilling using hedonic scales with

the consumer attributes identified in Table 2.

Single blade shear measurements were recorded on four separate sections per steak with 10 steaks/head size being subjected to shearing tests. The sections were 2.54 X 5.08 cm in size. Visual degree of doneness scores were assigned using an 8-point scale where 8 = very rare and 1 = very well done.

Results and Discussion

There was a tendency for both initial (5 chews) and final tenderness (15 chews) scores to increase (higher tenderness) as Comitrol head sizes increased (Table 1). Steaks made from ground beef had the highest tenderness. These results for tenderness agree most closely to those obtained at Natick Laboratories (Cardello, et al., 1983) for hardness on this same product. The smaller Comitrol head sizes reduced the amount of sensory panel connective tissue, which is in agreement with Cardello, et al., (1983). Juiciness scores were highest for ribeye steaks in our data, but were among the lowest in the Natick Laboratories study. Flavor intensity scores were highest for the smallest Comitrol head size (060) steak samples, and lowest for steaks made from ground beef. Sensory scores for flavor desirability were unaffected by flake size in the study of Durland, et al. (1982).

Consumer panel scores for the restructured steaks according to Comitrol head sizes is presented in Table 2. As in the Natick Laboratories study, intact muscle ribeye steaks were rated as having the most acceptable appearance. Steaks made from the 1610 head were rated low in visual appearance, and texture in both studies. In the Natick

Table 1. Effects of Comitrol head size on sensory panel scores.*

Head size, product	Value					
	Initial tenderness	Final tenderness	Initial connective tissue amount	Final connective tissue amount	Juiciness	Flavor intensity
Ribeye	5.3 ± 0.9^{d}	6.0 ± 0.8^{d}	5.4 ± 1.0^{b}	$6.0 + 1.0^{b}$	5.6 ± 0.9^{a}	4.6 ± 1.1^{b}
1610	4.5 ± 1.0^{e}	5.0 ± 1.0^{e}	4.1 ± 1.0^{d}	4.5 ± 1.1^{d}	5.1 ± 0.8^{ab}	4.9 ± 0.8^{ab}
1614	5.2 ± 1.0^{d}	5.6 ± 0.8^{d}	4.3 ± 0.7^{d}	4.8 ± 1.0^{cd}	5.3 ± 0.6^{ab}	5.0 ± 0.8^{ab}
1620	5.3 ± 1.2^{d}	5.7 ± 0.9^{d}	4.8 ± 1.1^{c}	5.2 ± 1.3^{c}	5.3 ± 0.7^{ab}	5.1 ± 1.0^{ab}
1628	5.5 ± 1.3^{d}	6.0 ± 0.8^{cd}	5.2 ± 0.8^{bc}	5.8 ± 1.0^{b}	5.0 ± 0.9^{b}	4.8 ± 0.9^{Ab}
750	6.0 ± 0.9^{c}	6.5 ± 0.6^{c}	5.6 ± 0.8^{b}	6.1 ± 0.9^{b}	5.3 ± 0.6^{ab}	4.9 ± 1.0^{ab}
060	6.6 ± 0.9^{b}	7.0 ± 0.8^{b}	6.5 ± 1.0^{a}	7.4 ± 0.7^{a}	5.5 ± 0.6^{a}	5.4 ± 0.9^{a}
Ground Beef	7.4 ± 0.7^{a}	7.5 ± 0.4^{a}	7.0 ± 0.5^{a}	7.4 ± 0.6^{a}	3.9 ± 0.5^{c}	3.8 ± 1.0^{c}

*Scores based on 8-point systems where 8 = extremely tender, juicy, intense in flavor, and none in connective tissue, while 1 = extremely tough, dry, bland and abundant in connective tissue. Values following means are standard deviations.

^{a,b,c,d,e}Means in the same column bearing different superscripts are significantly ($P<0.05$) different.

Table 2. Effects of Comitrol head size on consumer panel scores.*

Head size, product	Appearance		Texture		Flavor		Overall	
Batch =	2	3	2	3	2	3	2	3
Ribeye	7.1 ± 1.5^{a}	6.3 ± 2.4	6.8 ± 1.5^{a}	6.4 ± 2.3^{a}	5.7 ± 2.1	6.1 ± 2.2^{b}	6.1 ± 2.0	6.0 ± 2.2^{abc}
1610	5.1 ± 2.6^{c}	6.2 ± 1.7	4.7 ± 2.2^{c}	5.3 ± 2.2^{b}	6.4 ± 1.9	6.2 ± 2.0^{ab}	5.4 ± 2.1	5.8 ± 1.9^{bc}
1614	5.8 ± 1.9^{bc}	5.7 ± 2.0	5.0 ± 2.2^{bc}	4.9 ± 2.1^{b}	6.6 ± 1.7	6.7 ± 1.5^{ab}	5.8 ± 1.9	5.7 ± 1.9^{bc}
1620	6.0 ± 1.9^{bc}	5.9 ± 1.4	5.9 ± 1.9^{ab}	5.7 ± 1.5^{ab}	6.6 ± 1.7	6.8 ± 1.4^{ab}	6.2 ± 1.8	6.3 ± 1.3^{ab}
1628	6.2 ± 1.1^{abc}	6.4 ± 1.3	5.7 ± 1.6^{abc}	6.5 ± 1.1^{a}	6.4 ± 1.4	6.9 ± 1.0^{a}	6.1 ± 1.3	6.7 ± 1.1^{a}
750	6.3 ± 1.7^{ab}	6.5 ± 1.4	6.0 ± 2.0^{ab}	6.6 ± 1.3^{a}	6.7 ± 1.2	6.8 ± 1.2^{ab}	6.4 ± 1.7	$6.6 + 1.2^{a}$
510	5.9 ± 2.0^{bc}	----	5.8 ± 2.1^{abc}	----	6.8 ± 1.9	----	6.2 ± 1.8	----
060	6.1 ± 1.9^{abc}	6.4 ± 1.4	5.8 ± 2.2^{abc}	6.6 ± 1.4^{a}	6.1 ± 2.0	7.1 ± 0.8^{a}	5.8 ± 2.0	6.7 ± 1.0^{a}
Ground beef	----	5.9 ± 1.7	----	5.4 ± 2.0^{b}	----	5.1 ± 1.9^{c}	----	5.4 ± 1.9^{c}

*Scores based on 8-point systems where 8 = like extremely and 1 = dislike extremely. Values following means are standard deviations.

[a,b,c]Means in the same column bearing different superscripts are significantly ($P<0.05$) different.

Laboratories study, the consumer panelists rated the ribeye steak as more acceptable in texture than all other products. However, batch 3 scores for appearance were unaffected by particle size. While ribeye steaks received the highest texture desirability scores in our study, it was not significantly ($P>0.05$) different than intermediate and small flake size restructured steaks. The low acceptability for texture in steaks made from the 1610 and 1614 head were found in both batches, in our study, as well as the Natick Laboratories study. Durland, et al. (1982) and Seideman, et al. (1982b) also found smaller flake size steaks to have higher texture desirability scores.

Flavor desirability scores were not affected by flake size in batch one steaks; but steaks from ground beef received the lowest ratings for flavor desirability in batch 3. No differences ($P>0.05$) were found for flavor desirability in Natick Laboratories consumer tests. Overall acceptability patterns were similar between our studies and those of Natick Laboratories. In our study, ground beef steaks received the lowest ratings for overall desirability ($P<0.05$). While this was true in the Natick Laboratories study, desirability scores for ground beef steaks were not different from those of all other flake size steaks.

The Instron values (Table 3) for the Comitrol head sizes showed a similar trend (lower values with smaller flake sizes) to those reported by Cardello, et al. (1983) and Seideman, et al. (1982b).

Steaks cooked by the broiling method (Table 4) yielded similar cooking losses regardless of head size. However, when grilling was used, ribeye steaks and the larger flake size steaks produced higher ($P<0.05$) cooking losses than the smaller flake size steaks. Previous studies (Costello, et al., 1981; Durland, et al., 1982; Seideman, et al., 1982ab)

Table 3. Effects of Comitrol head size on Instron single blade shear force values.

Head size, product	Values* Batch 2	Batch 3
Ribeye	16.5 ± 0.9^{a}	14.5 ± 1.3^{b}
1610	16.6 ± 0.8^{a}	19.0 ± 3.2^{a}
1614	15.1 ± 1.7^{a}	17.6 ± 1.3^{a}
1620	11.0 ± 0.9^{b}	17.8 ± 0.9^{a}
1628	10.3 ± 0.8^{b}	12.0 ± 1.8^{bc}
750	14.3 ± 1.6^{a}	10.2 ± 1.3^{cd}
510	16.5 ± 2.9^{a}	----
060	9.8 ± 1.3^{b}	8.4 ± 1.1^{ed}
Ground beef	----	7.5 ± 0.9^{e}

*Values are in kg.

[a,b,c,d,e]Means in the same column bearing different superscripts are significantly (P<0.05) different.

Table 4. Effects of Comitrol head size on cooking properties.

Head size, product	Cooking loss, %				Degree of doneness score*			
	Sensory panel batch 3	Consumer panel batch 2	Instron steaks batch 2	Instron steaks batch 3	Sensory panel batch 3	Consumer panel batch 2	Instron steaks batch 2	Instron steaks batch 3
Ribeye	27.0 ± 3.3^{b}	32.6 ± 2.8^{a}	23.7 ± 0.5	27.2 ± 2.0^{b}	4.4 ± 0.5	2.5 ± 1.3	5.0 ± 0.0^{a}	5.0 ± 0.8^{a}
1610	26.9 ± 3.6^{b}	22.9 ± 3.3^{b}	21.2 ± 3.0	26.4 ± 1.9^{b}	3.8 ± 1.5	3.5 ± 0.6	3.0 ± 0.0^{b}	2.5 ± 0.6^{b}
1614	26.5 ± 4.1^{b}	24.5 ± 0.5^{b}	21.1 ± 5.6	24.7 ± 2.4^{b}	3.5 ± 1.0	2.5 ± 0.6	3.0 ± 0.0^{b}	3.2 ± 0.5^{b}
1620	28.1 ± 4.3^{b}	24.5 ± 2.0^{b}	23.2 ± 4.1	27.4 ± 2.1^{b}	3.6 ± 1.1	2.5 ± 0.6	3.0 ± 0.0^{b}	4.5 ± 0.6^{b}
1628	28.9 ± 5.7^{b}	15.1 ± 4.6^{c}	22.3 ± 2.7	26.0 ± 3.2^{b}	3.5 ± 1.2	3.0 ± 0.0	3.0 ± 0.0^{b}	2.8 ± 0.5^{b}
750	24.9 ± 4.8^{b}	17.6 ± 3.1^{c}	26.8 ± 3.3	26.0 ± 3.8^{b}	3.4 ± 0.5	2.8 ± 0.5	2.0 ± 0.0^{c}	3.2 ± 0.5^{b}
510	----	17.4 ± 1.4^{c}	26.0 + 3.7	----	----	3.0 ± 0.0	3.2 ± 0.5^{b}	----
060	24.8 ± 2.9^{b}	16.8 ± 4.2^{c}	21.9 ± 1.7	22.9 ± 4.0^{b}	3.0 ± 1.0	2.5 ± 0.6	2.0 ± 0.0^{c}	2.5 ± 0.6^{b}
Ground Beef	36.1 ± 2.7^{a}	----	----	34.6 ± 4.0^{a}	2.5 ± 0.6	----	----	3.0 ± 0.8^{b}

*Scores based on an 8-point scale where 8 = very well done and 1 = very rare.

[a,b,c]Means in the same column bearing different superscripts are significantly ($P<0.05$) different.

failed to indicate any differences in cooking losses attributable to flake size. In only one out of four tests did degree of doneness scores differ among the various head sizes - products. Costello, et al. (1981), Durland, et al. (1982) and Seideman, et al. (1982b) found no differences in scores for degree of doneness attributable to flake size.

Conclusions

Similar to data reported by Natick Laboratories, it would appear that for some attributes, trained sensory and consumer panelists rate restructured steaks intermediate to ribeye steak and steak processed from ground beef. However, the panelists found more connective tissue and higher beef flavor intensity in the restructured steaks compared to ribeye and ground beef steaks. Smaller Comitrol head sizes generally received scores indicative of higher tenderness and less connective tissue. Batch to batch variations were found especially for Instron values. Cooking losses appear similar between flake sizes when broiling was used on restructured steaks, but when grilling was used, steaks processed from larger flake particles lost more weight in cooking than steaks processed from smaller flake particles.

EFFECTS OF ANATOMICAL LOCATION OF MUSCLES, PLANT SOURCE AND TIME OF BONING ON SENSORY, INSTRON AND COOKING CHARACTERISTICS OF RESTRUCTURED BEEF STEAKS

Introduction

At the time of initiation of this study, several studies had been completed at Natick Laboratories and one at the Meat Science Research Laboratory which indicated that at least some of the textural variability in restructured beef steaks from batch to batch could be attributable to variations in the amount of connective tissue. Booren, et al. (1981) found higher levels of sensory panel determined connective tissue in restructured steaks made from US Standard rounds vs those made from US Choice chucks. Reducing the effects of connective tissue in restructured products has been identified as a high priority research area (Breidenstein, 1982; Secrist, 1982).

Materials and Methods

USDA Choice square cut chucks and rounds (minus knuckle) were procured from three sources and trimmed of heavy connective tissue, exposed ligaments and tendons, backstrap, heavy connective tissue of the scapular joint, the subscapularis muscle and the chuck cover. The same team of trimmers repeated these procedures on second and third consecutive days with the chucks and rounds from the three sources. Thus, a total of 18 treatment combinations (2 muscles X 3 plant sources X 3 days) were attained. Processing of the restructured steaks (conducted at Natick Laboratories) was as defined for the first project on head sizes. The Comitrol 750 head size was used for all treatments.

Descriptive attribute panel testing, broiling and Instron testing was described for the first head size study. Collagen determinations followed the procedures of Hill (1966) and Bergman and Loxley (1963).

Results and Discussion

Most of the characteristics evaluated on the restructured steaks of this study were affected only by the main effects and were not involved in interactions. With the exception of flavor intensity, restructured steaks manufactured from beef chucks were rated higher in sensory traits than steaks made from rounds (Table 5). This is in contrast, for tenderness and connective tissue, to the results published by Booren, et al. (1981). The plant source had no effect on sensory panel scores. Juiciness scores were highest for steaks made from the first day of boning, while the product made after the third day of boning was scored as lower in beef flavor intensity to steaks processed from the boneless meat of the first day of boning. Flavor intensity scores were involved in an interaction effect ($P<0.05$) between anatomical location of muscles and plant source (Table 6). The interaction appears to center around the high flavor intensities assigned to restructured steaks from round muscle of plant C and the low flavor intensities of restructured steaks from chuck muscle obtained from plant C.

Cooking and Instron data are provided in Table 7. Cooking losses were unaffected by the main effects of this study. Instron single blade shear force measurements also did not differ between steaks from the two muscles. Booren, et al. (1981) found restructured steaks from rounds to require less force in shearing than steaks from chucks. Cooking loss values were involved in an interaction of plant source with muscle

Table 5. Effects of anatomical location of muscles, plant source and time of boning on sensory panel scores.*

Source of variation	Value					
	Initial tenderness	Final tenderness	Initial connective tissue amount	Final connective tissue amount	Juiciness	Flavor intensity
Anatomical location of muscles						
Round	5.5^{b}	5.8^{b}	4.9^{b}	5.2^{b}	5.2^{b}	4.1
Chuck	6.1^{a}	6.3^{a}	5.3^{a}	5.6^{a}	5.5^{a}	4.5
Plant source						
A	6.0	6.2	5.2	5.5	5.5	4.3
B	5.8	6.0	5.1	5.5	5.2	4.2
C	5.8	6.0	4.9	5.2	5.4	4.5
Day of boning						
1	5.9	6.2	5.1	5.4	5.6^{a}	4.6^{a}
2	5.8	6.0	5.0	5.3	5.2^{b}	4.3^{ab}
3	5.7	6.0	5.1	5.3	5.3^{b}	4.1^{b}

*Scores based on 8-point systems where 8 = extremely tender, juicy, intense in flavor and none in connective tissue, while 1 = extremely tough, dry, bland and abundant in connective tissue.

[a,b]Means in the same column bearing different superscripts are significantly ($P<0.05$) different.

Table 6. Effects of anatomical location of muscles and plant source on flavor intensity scores.*

	Anatomical location	
Plant source	Round	Chuck
A	3.9 $\pm$ 0.4	4.7 $\pm$ 0.1
B	4.0 $\pm$ 0.2	4.8 $\pm$ 0.3
C	4.5 $\pm$ 0.6	4.4 $\pm$ 0.1

*Scores based on an 8-point system where 8 = extremely intense and 1 = extremely bland. Interaction of plant source and anatomical location was significant ($P<0.05$).

Table 7. Effects of anatomical location of muscles, plant source and time of boning on cooking properties and Instron single blade shear force values.

	Values		
Source of variation	Cooking loss, %	Cooked steak thickness, in.	Instron single blade shear force, kg.
Anatomical location of muscles			
Round	23.9	0.63	15.6
Chuck	26.2	0.65	15.5
Plant source			
A	24.8	0.63[b]	14.3
B	26.2	0.62[b]	15.3
C	24.1	0.68[a]	16.6
Day of boning			
1	24.0	0.63[b]	15.7
2	26.2	0.63[b]	15.7
3	25.0	0.67[a]	15.3

[a,b]Means in the same column bearing different superscripts are significantly ($P<0.05$) different.

location (Table 8). The interaction was similar (high value for round steaks from plant C, low value for chuck steaks from plant C) to that noted for beef flavor intensity (Table 6). There is some indication on just a mean basis that steaks with higher cooking losses had higher beef flavor intensity.

Table 9 gives collagen and soluble collagen values according to the main effects of the project. Since all these main effects were involved in an interaction for collagen values, discussion on these results is not appropriate. The interaction of muscle with time of boning is represented in Table 10. If collagen values are a good measure of the physical removal of connective tissue via boning, then it would appear as time went on the boners were removing less of the connective tissue from the round muscles and more of the connective tissue from the chuck muscles. For the round muscles, it would appear that the collagen being left as time progressed was more of the insoluble type. In the case of the chuck muscles, the greater amount of connective tissue being removed as time progressed would appear to be of the insoluble type. It would appear that for both round and chuck muscles, plant C product had less soluble collagen when round muscle steaks were compared to plant A round steaks and chuck steaks were compared to both plant A and B steaks (Table 11). The plant by day interaction (Table 12) indicates that less connective tissue was left on the third day for plants A and B, but more was left on the third day for plant C steaks. Furthermore, the solubility of the collagen in the steaks increased between the first and third days for plants A and B, but decreased for plant C steaks.

Table 8. Effects of anatomical location of muscles and plant source on cooking loss of restructured steaks.*

	Anatomical location of muscles	
Plant source	Round	Chuck
A	21.2	28.4
B	24.8	27.6
C	25.7	22.5

*Interaction of anatomical location of muscles and plant source was significant ($P<0.05$).

Table 9. Effects of anatomical location of muscles, plant source and time of boning on collagen values.*

Source of variation	Collagen mg/g	Soluble collagen %
Anatomical location of muscles		
Round	10.0	8.1
Chuck	10.7	17.8
Plant source		
A	10.5	14.6
B	10.8	13.1
C	9.8	12.2
Day of boning		
1	10.7	11.2
2	10.3	14.1
3	10.1	14.6

*All main effects were involved in significant ($P<0.05$) interacions.

Table 10. Effects of anatomical location of muscles and time of boning on collagen values.*

Muscle, day	Values: Collagen mg/g	Values: Soluble collagen %
Round--day 1	9.3	8.5
Round--day 2	10.0	8.1
Round--day 3	10.8	7.7
Chuck--day 1	12.2	13.9
Chuck--day 2	10.6	17.9
Chuck--day 3	9.4	21.6

*Interaction of anatomical location of muscles and time of boning was significant ($P<0.05$).

Table 11. Effects of anatomical location of muscles and plant source on percent soluble collagen.*

	Anatomical location of muscles	
Plant source	Round	Chuck
A	9.8	19.7
B	7.2	19.0
C	7.0	14.9

*Interaction of anatomical location of muscles and plant source was significant ($P<0.05$).

Table 12. Effects of plant source and time of boning on collagen values.*

Plant, day	Values Collagen mg/g	 Soluble collagen %
Plant A--day 1	10.3	13.8
Plant B--day 1	12.0	11.1
Plant C--day 1	9.9	16.4
Plant A--day 2	11.4	13.1
Plant B--day 2	10.9	11.9
Plant C--day 2	8.8	14.9
Plant A--day 3	9.8	17.0
Plant B--day 3	9.5	16.4
Plant C--day 3	11.0	10.6

*Interaction of plant source and time of boning was significant ($P<0.05$) for both values.

Conclusions

Using the trimming procedures of this study, it would appear that restructured steaks from chuck muscles rate higher in sensory traits than those obtained from round muscles. There is some indication that flavor intensity of restructured steaks may be related to the amount of cooking loss. Using collagen and soluble collagen values as the basis for variation in connective tissue between sources (plants) and days of trimming, it would appear that some sizeable day to day and plant to plant variation can occur. However, it does not appear that this variation greatly influenced the sensory properties of the subsequent restructured beef steaks.

DETERMINATION OF THE EFFECTS OF SLOW WATER BATH COOKING, STEAK TO STEAK VARIATION AND INDUSTRY PROCEDURES ON CHARACTERISTICS OF RESTRUCTURED BEEF STEAKS

Introduction

At this point in time, it was becoming increasingly apparent that textural variations were occurring in the restructured steaks when considerable efforts in processing and cooking were being taken to prevent this. It was determined that perhaps steaks from even the same log were not reacting in the same fashion to cooking. A considerable amount of distortion, swelling, variation in thickness and degree of doneness was being observed following cooking on the Faberware broilers. In an attempt to learn more about how minute changes in temperature affect restructured steaks, a study involving the cooking of restructured steaks in vacuum bags in a water bath was initiated.

Also, in order to obtain greater information on the amount and degree of variation in tenderness, more shears were obtained per steak. Concerning the possibility that restructured steaks processed in industry did not possess the textural variations noticed in the steaks processed at Natick, restructured steaks from DPM were obtained and subjected to sensory, cooking and Instron testing.

Materials and Methods

End point temperatures of 60, 63, 66, 69, 72 and 75° C were selected. For cooking, the water temperature was set at the final end-point temperature for the particular steaks being cooked. Steaks were placed in

a seal-a-meal bag. Clamps were put along the bottom and sides to provide weight. The top of the bag was folded over a metal bar and clipped. The steaks were submerged under the water for two min., after which it was removed and thermocouples were inserted. The steaks, were replaced back into the bags and they were sealed with heat. The bags were weighed and cooking proceeded until the final internal temperature was reached.

Steaks from two industry sources were obtained for evaluation. One test was conducted at Loggins in Tyler, Texas, by Natick Laboratories and the other was restructured beef steaks obtained by the Meat Science Research Laboratory from DPM International in Arkansas. Steaks used to determine the maximum Instron variability were processed by Natick Laboratories using a Comitrol 750 head. Cooking, sensory and Instron procedures have been previously described in this report. Thickness of cooked steaks was also recorded.

Results and Discussion

As the final internal temperature increased (thus also cooking time) during water bath cooking of restructured steaks, the cooking losses increased (Table 13). Thickness of steaks during cooking increased with some rise in temperature (66° C vs 60° C), but then decreased between 60 and 72° C. Instron single blade shear force followed no particular trend with the highest values being for steaks cooked to 60, 69, 75° C. However, the values are certainly much less with a considerable reduction in variability over those obtained with 750 restructured steaks cooked by broiling. This indicates that cooking can affect the textural properties of restructured steaks. While water bath cooking of steaks in sealed pouches isn't practical nor probably capable of providing the desired

Table 13. Effects of internal temperature during water bath cooking on cooking properties and Instron single blade shear force values.

	Values			
Temperature, °C	Cooking loss, %	Center steak thickness, in.	Side steak thickness, in.	Instron single blade shear force, kg.
60	6.1 ± 0.3^{e}	$0.58 \pm .04^{abc}$	$0.58 \pm .02^{c}$	12.2 ± 1.4^{a}
63	9.2 ± 1.4^{d}	$0.56 \pm .03^{bc}$	$0.60 \pm .03^{bc}$	10.8 ± 1.0^{c}
66	15.0 ± 2.6^{c}	$0.68 \pm .07^{a}$	$0.67 \pm .03^{ab}$	10.8 ± 0.7^{b}
69	17.5 ± 1.9^{b}	$0.66 \pm .12^{ab}$	$0.69 \pm .12^{a}$	12.3 ± 1.2^{a}
72	19.3 ± 2.1^{b}	$0.55 \pm .08^{c}$	$0.62 \pm .04^{abc}$	10.7 ± 0.6^{b}
75	23.2 ± 0.8^{a}	$0.64 \pm .08^{abc}$	$0.62 \pm .08^{abc}$	12.8 ± 0.7^{a}

[a,b,c,d,e]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

textural properties, it nevertheless shows that it might have some promise as a research tool for reducing textural variability. The lessening of the variability is probably due to the absence of crust formation during cooking in a sealed pouch.

Efforts to determine the magnitude of within and between steak variability in shear force is given in Table 14. The values on a mean basis for individual steaks range from 10.9 to 18.8 kg., which certainly overlaps numerous other Comitrol head sizes reported in Table 3. Variability within steaks is also quite large (range in S.D. = 0.79-5.00). High or low degrees of within-steak variability do not necessarily seem to be associated with high or low mean shear values. Variation in mean thickness values (0.48-0.77 in) also seems large and illustrates the problems related to distortion. Since three thickness measurements were taken, the standard deviations illustrate the fact that for some steaks a considerable degree of within-steak variability was present in thickness.

Steaks obtained from the production run in Texas yielded considerably less cooked weight than any other studies in this report (Table 15). However, they were also much smaller (90 g) than restructured steaks in other studies. Instron single blade shear values, however, were higher than what was found for 750 steaks made at Natick Laboratories.

Steaks manufactured at DPM International were compared to some steaks from Natick Laboratories which were also processed to have large particle sizes (Table 16). Thin steaks were cut 0.40 in and thick steaks were cut 0.67 in. DPM thin steaks were: (1) rated higher in tenderness than DPM thick steaks, 1614 and ribeye steaks; (2) classified as having less connective tissue than all Natick Laboratories processed steaks, and (3) scored higher in juiciness than DPM thick steaks and 1614 steaks.

Table 14. Between and within restructured steak variation in cooked steak thickness and Instron values.

Steak number	Cooked steak thickness, in.	Instron single blade shear force, kg.
1	0.68 ± .06[b]	15.3 ± 1.68[bcde]
2	0.60 ± .01[bcde]	12.2 ± 5.00[efg]
3	0.56 ± .05[def]	12.5 ± 2.34[efg]
4	0.56 ± .06[def]	11.7 ± 1.52[fg]
5	0.57 ± .06[cdef]	12.7 ± 2.22[efg]
6	0.57 ± .04[bcdef]	13.4 ± 2.59[defg]
7	0.48 ± .04[f]	10.9 ± 2.53[g]
8	0.58 ± .03[bcdef]	16.9 ± 1.47[abc]
9	0.66 ± .01[bc]	12.7 ± 2.63[efg]
10	0.60 ± .06[bcde]	12.8 ± 3.63[efg]
11	0.61 ± .07[bcde]	18.0 ± 2.27[ab]
12	0.58 ± .09[bcdef]	14.5 ± 2.62[cdef]
13	0.66 ± .01[bcd]	15.3 ± 2.41[bcde]
14	0.67 ± .01[bc]	16.6 ± 2.27[abcd]
15	0.64 ± .03[bcd]	18.8 ± 1.49[a]
16	0.60 ± .02[bcde]	14.3 ± 1.25[cdefg]
17	0.77 ± .10[a]	15.4 ± 1.98[bcde]
18	0.62 ± .03[bcd]	14.8 ± 0.79[bcdef]
19	0.52 ± .01[ef]	16.8 ± 2.82[abcd]
20	0.51 ± .09[ef]	14.1 ± 1.71[cdefg]

[a,b,c,d,e,f,g]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Table 15. Cooking and Instron properties for restructured beef steaks obtained from different industry production tests.

	Values		
Production test	Cooking loss, %	Cooked steak thickness, in.	Instron single blade shear force, kg.
68	59.6 ± 6.4[a]	0.56 ± .02	20.6 ± 3.1
144	49.2 ± 3.1[b]	0.60 ± .07	22.9 ± 3.4
146	49.0 ± 2.6[b]	0.62 ± .01	21.9 ± 0.8
148	50.9 ± 1.4[b]	0.57 ± .02	20.5 ± 1.3

[a,b]Means in the same column bearing different superscripts are significantly ($P<0.05$) different.

Table 16. Comparison of industry (DPM) processed thick and thin restructured steaks with large particle Comitrol restructured steaks and ribeye steaks.*

Characteristic	Treatment				
	DPM thin steak	DPM thick steak	Comitrol 1620 head	Comitrol 1614 head	Ribeye steak
Sensory panel					
Initial tenderness	6.5[a]	5.7[b]	5.9[ab]	5.5[b]	4.2[c]
Final tenderness	6.5[a]	5.9[b]	5.9[ab]	5.9[b]	5.0[b]
Initial connective tissue amount	5.4[a]	5.1[ab]	4.4[b]	4.7[b]	4.5[b]
Final connective tissue amount	5.6	5.3	4.8	5.0	5.0
Juiciness	6.0[a]	5.5[b]	5.6[ab]	5.5[b]	5.5[ab]
Flavor intensity	4.4	4.5	4.7	4.9	3.8
Cooking properties					
Cooking loss, %	22.0 $\pm$ 2.6[b]	31.5 $\pm$ 4.0[a]	--	--	--
Cooked steak thickness, in.	0.39 $\pm$ .01[b]	0.61 $\pm$ .01[a]	--	--	--
Instron					
Single blade shear force, kg.	14.2 $\pm$ 1.6	15.2 $\pm$ 2.1	--	--	--

*Scores based on 8-point systems where 8 = extremely tender, juicy, intense in flavor and none in connective tissue, while 1 = extremely tough, dry, bland and abundant in in connective tissue.

[a,b,c]Means in the same row bearing different superscripts are significantly ($P<0.05$) different.

Conclusions

Cooking of steaks in sealed pouches in a water bath reduced variability in shear force values probably due to the absence of crust formation. Although increased final internal cooked meat temperatures resulted in higher cooking losses, they had no effect on shear force values. Intensive shearing of steaks (750 head size) illustrated the fact that a considerable amount of variation in at least shear force exists within and between steaks. Unless this variation can be reduced, the possibility of developing useful mechanical approaches to separating restructured steaks on the basis of textural differences is doubtful. Steaks processed under industry conditions also appear to have substantial variations in shear force.

DEVELOPMENT OF A TEXTURE PROFILE PANEL USING RESTRUCTURED BEEF STEAKS MADE FROM VARIOUS COMITROL HEADS

Introduction

It was realized that while a sensory approach for use in procurement decisions by a large agency such as DOD was probably out of the question, nevertheless, it could be useful in identifying the textural properties that were consistently affected by processing and/or cooking. At the time of this study, the use of a texture profiling approach to restructured steaks had not been reported. Since then, Cardello, et al., (1983) has reported on its use and application at Natick Laboratories.

Materials and Methods

A texture profile panel of 10 members was developed over a six-month period after screening and training of 135 people. Intensive training of the final 10-member panel took four months. Considerable refining and elimination of texture terms as related to restructured steaks, occurred during this time period. The data presented here is the first to be evaluated following their certification by the Meat Science Research Laboratory and Gail Civille, who trained the panel. The various definitions and procedures used by the panel are given in Appendix Table 1.

Broiling procedures are the same as those provided in the first study of this report. Since a considerable amount of time is involved in texture profiling samples of a given treatment, it was necessary to determine whether the time required to hold samples in a warmer had any

affect on shear force, visual degree of doneness and internal sample temperature.

Results and Discussion

The texture profile panel found, on a visual basis, steaks from ground beef to have less distortion than restructured beef steaks, regardless of head size (Table 17). Ground beef steaks and 060 steaks were both scored as smoother in appearance than 1610 and 750 steaks. Fibrousness decreased as head sizes decreased. Costello, et al. (1981) found the textural appearance of flaked steaks (240 head) to be more coarse than ground beef steaks. Durland, et al. (1982) observed coarse flaked steaks to be rated too coarse in texture and fine or small particle steaks to be too fine in visual texture appearance. In our study, impression values in the 1610 steaks were similar to ground beef steaks, but greater than those values assigned to steaks from the 060 head. Cardello, et al. (1983) reported increased springiness (similar to our impression) as head sizes decreased.

Ground beef steaks were rated as less hard, cohesive and dense on first bite than restructured steaks. Moisture release decreased and uniformity of first bite increased as head size in flaking decreased. The absence of differences in first bite cohesiveness is similar to those found by Cardello, et al. (1983).

During mastication, the most distinct differences between head sizes were noted for juiciness, cohesiveness of the mass at 15 chews, uniformity of mass and gristle. Cardello, et al. (1983) also found similar and distinct trends between these head sizes for cohesiveness of mass and amount of connective tissue. Coarseness does not appear to be a textural

Table 17. Effects of Comitrol head size on texture profile panel scores.

Characteristic[a]	Head size 1610	750	060	Ground beef
Visual				
Distortion	6.2 ± 3.1[bc]	5.7 ± 2.1[c]	7.1 ± 2.8[b]	3.0 ± 1.1[d]
Smoothnesss	6.5 ± 1.6[c]	6.4 ± 2.3[c]	8.7 ± 2.2[b]	8.9 ± 2.9[b]
Fibrousness	9.1 ± 1.8[b]	7.4 ± 1.6[c]	3.8 ± 2.1[d]	1.9 ± 0.9[e]
Partial compression				
Impression	5.4 ± 2.6[bc]	5.8 ± 2.3[b]	3.6 ± 1.9[c]	6.2 ± 2.8[b]
First bite				
Hardness	8.1 ± 1.7[b]	5.7 ± 1.4[c]	5.8 ± 1.8[c]	3.6 ± 1.2[d]
Cohesiveness	7.5 ± 2.5[b]	7.2 ± 2.3[b]	8.0 ± 1.7[b]	5.2 ± 1.8[c]
Density	8.8 ± 2.2[b]	7.1 ± 2.1[c]	8.2 ± 2.1[bc]	5.2 ± 1.2[d]
Moisture release	9.3 ± 2.4[b]	7.1 ± 2.1[c]	5.2 ± 3.0[d]	3.8 ± 1.5[e]
Uniformity	4.1 ± 1.8[d]	7.1 ± 2.5[c]	10.5 ± 1.5[b]	10.8 ± 1.3[b]
Mastication				
Chunkiness	9.1 ± 2.7[b]	6.2 ± 2.6[c]	4.6 ± 1.5[c]	4.0 ± 1.6[c]
Juiciness	9.3 ± 1.8[b]	8.1 ± 1.9[c]	6.1 ± 2.4[d]	4.8 ± 1.7[e]
Cohesiveness of mass, 15 chews	8.8 ± 2.4[b]	6.7 ± 2.1[c]	6.1 ± 2.4[c]	4.2 ± 1.1[d]
Cohesiveness of mass, 25 chews	9.0 ± 1.9[b]	7.1 ± 2.1[c]	6.1 ± 2.1[c]	4.4 ± 1.7[d]
Coarseness of mass 15 chews	8.1 ± 1.8	8.5 ± 2.0	7.5 ± 2.0	7.7 ± 2.5
Coarseness of mass 25 chews	6.4 ± 2.1	6.6 ± 1.5	6.0 ± 2.2	5.3 ± 2.2
Uniformity of mass	4.1 ± 1.9[d]	7.0 ± 2.4[c]	10.0 ± 2.2[b]	11.2 ± 1.4[b]
Gristle	6.2 ± 3.2[b]	3.9 ± 3.1[c]	0.3 ± 0.5[d]	0.4 ± 0.7[d]
Webbed tissue	7.9 ± 2.4	4.9 ± 2.3	1.2 ± 1.2	0.7 ± 0.9
Number of chews	63.1 ± 9.9[b]	53.3 ± 9.8[c]	48.2 ± 8.4[c]	39.5 ± 6.9[d]
After swallow				
Particles	3.1 ± 1.3	3.0 ± 1.2	3.2 ± 1.5	3.5 ± 1.9
Tooth pack	3.6 ± 1.6	2.7 ± 1.6	1.8 ± 1.1	1.8 ± 1.8
Mouth coating	5.6 ± 2.2[b]	4.0 ± 1.4[c]	3.6 ± 1.3[c]	3.5 ± 2.2[c]

[a]Definitions for the various characteristics are given in Appendix Table 1.

[b,c,d,e]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

property that: (1) is of importance with this product, or (2) differs between head sizes. Juiciness, cohesiveness of mass and gristle values for ground beef steaks were all lower ($P<0.05$) than those obtained for any particle size of restructured steaks.

The holding of restructured steak samples in a warmer for up to 31 min failed to produce any differences at 3 min intervals for Instron values and degrees of doneness (Table 18). The temperature of the product did undergo some reductions over this time period.

Conclusions

The texture profile panel developed for this study, upon completion of their training, found uniform differences between substantially different Comitrol head sizes for fibrousness, first bite moisture release and uniformity, cohesiveness and uniformity of mass and gristle. The need to hold samples for a prolonged period of time in a sample warmer does not appear to affect texture as measured by the Instron.

Table 18. Effects of holding times in a warmer on Instron values, degree of doneness scores and internal temperatures.

Holding time, min	Maximum shear force, lbs	Newtons/ cm^2	Degree of doneness score	Temperature °C
10	19.4 ± 3.7	10.9 ± 2.4	3.8 ± .77	39.3 ± 1.1[a]
13	18.6 ± 5.3	10.3 ± 3.3	3.7 ± .63	38.0 ± 1.3[b]
16	18.1 ± 4.6	9.3 ± 3.0	3.3 ± .92	37.9 ± 1.5[b]
19	17.7 ± 5.2	10.0 ± 3.1	3.2 ± .87	36.4 ± 1.3[c]
22	20.9 ± 9.5	11.6 ± 5.3	3.2 ± .59	36.0 ± 2.0[c]
25	17.3 ± 5.4	9.1 ± 2.7	3.0 ± .50	36.1 ± 1.4[c]
28	20.4 ± 5.5	10.9 ± 2.3	3.1 ± .50	35.8 ± .91[c]
31	17.7 ± 3.5	10.0 ± 2.3	2.7 ± .63	35.0 ± .82[d]

[a,b,c,d]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

EFFECTS OF FLAKE SIZE AND SAMPLE SERVING TEMPERATURE ON TEXTURE PROFILE, INSTRON AND COOKING CHARACTERISTICS OF RESTRUCTURED BEEF STEAKS

Introduction

Traditionally, samples for sensory evaluation are consumed warm or very shortly after cooking, while samples intended for shear tests are usually allowed to cool to room temperature at the very least. The intent of this study was to determine if sample temperature (hot = right after cooking, warm = room temperature) exerted any difference on textural attributes as measured by panel and Instron.

Materials and Methods

Five restructured steak products [160, 750A and B (A and B refer to different processing times), 060 and ground beef] were manufactured at Natick Laboratories for this study. Steaks were cooked on Faberware grills as has been previously described in the first study. Steaks intended to be served or sheared "hot" were placed in a sample cutting box immediately upon cooking and cut into 2.54 cm^2 sections. Samples for the "warm" serving temperature were allowed to come to room temperature before cutting, serving and shearing.

Results and Discussion

Upon visual examination by the texture profile panel, 060 and ground beef steaks were found to be more smooth, but less fibrous (Table 19) than 750 and 1610 restructured steaks. Values and trends for first bite

Table 19. Effects of Comitrol head size on texture profile panel scores.

Characteristic[a]	1610	750A	750B	060	Ground beef
Visual					
Smoothness	7.5 ± 1.9^{c}	8.1 ± 2.5^{c}	7.9 ± 1.5^{c}	9.5 ± 2.3^{b}	9.9 ± 1.8^{b}
Fibrousness	10.3 ± 1.6^{b}	$8.3 \pm .53^{c}$	7.2 ± 1.9^{c}	4.9 ± 1.0^{d}	3.0 ± 1.8^{e}
Partial compression					
Impression	6.4 ± 2.8	5.4 ± 4.3	5.1 ± 2.4	$5.2 \pm .98$	6.4 ± 2.8
First bite					
Hardness	8.2 ± 2.2^{b}	5.8 ± 1.8^{c}	6.5 ± 1.5^{c}	7.1 ± 1.6^{bc}	4.2 ± 1.7^{d}
Cohesiveness	8.8 ± 1.7^{b}	$6.6 \pm .93^{c}$	7.7 ± 2.1^{bc}	7.7 ± 2.8^{bc}	5.4 ± 1.8^{d}
Density	8.6 ± 1.2^{bc}	7.6 ± 2.7^{c}	8.3 ± 1.2^{bc}	8.8 ± 1.4^{b}	6.6 ± 1.8^{d}
Uniformity	5.0 ± 1.6^{d}	8.8 ± 2.7^{c}	8.7 ± 1.3^{c}	11.2 ± 1.6^{b}	11.1 ± 1.5^{b}
Mastication					
Juiciness	8.2 ± 1.2^{b}	$6.2 \pm .93^{c}$	7.9 ± 1.7^{b}	5.6 ± 2.1^{c}	4.1 ± 1.1^{d}
Size of chewed particles	2.5 ± 1.4^{c}	2.4 ± 1.3^{c}	2.6 ± 1.1^{c}	2.6 ± 1.5^{c}	3.4 ± 1.2^{b}
Cohesiveness of mass--15 chews	8.8 ± 1.2^{b}	7.0 ± 2.1^{cd}	7.6 ± 1.6^{c}	6.0 ± 1.6^{de}	4.9 ± 1.7^{e}
Cohesiveness of mass--25 chews	9.2 ± 1.0^{b}	7.2 ± 2.6^{c}	7.2 ± 1.7^{c}	5.9 ± 2.0^{cd}	4.8 ± 1.6^{d}
Coarseness of mass--15 chews	8.6 ± 1.9^{b}	7.2 ± 1.7^{c}	7.4 ± 1.7^{c}	7.3 ± 2.5^{c}	7.2 ± 2.5^{c}
Coarseness of mass--25 chews	6.6 ± 2.0^{b}	5.1 ± 2.1^{d}	6.0 ± 1.6^{bc}	5.7 ± 2.4^{cd}	5.3 ± 2.6^{cd}
Uniformity of mass	5.5 ± 2.3^{d}	9.2 ± 1.5^{c}	9.3 ± 1.6^{c}	11.1 ± 1.5^{b}	$11.8 \pm .79^{b}$
Gristle	6.1 ± 1.8^{b}	3.1 ± 3.0^{c}	2.2 ± 1.6^{c}	$0.3 \pm .74^{d}$	$0.2 \pm .20^{d}$
Webbed tissue	6.9 ± 2.2^{b}	3.8 ± 2.0^{c}	2.7 ± 1.6^{d}	$0.6 \pm .95^{e}$	$0.4 \pm .53^{e}$
Number of chews	72.0 ± 9.0^{b}	57.4 ± 9.0^{c}	59.2 ± 7.6^{c}	54.0 ± 7.2^{c}	46.7 ± 7.4^{d}
After swallow					
Tooth pack	2.8 ± 1.0^{b}	2.3 ± 2.4^{b}	$2.1 \pm .95^{bc}$	$1.6 \pm .49^{cd}$	$1.3 \pm .54^{d}$
Mouth coating	4.4 ± 1.5^{b}	$3.4 \pm .97^{cd}$	3.8 ± 1.5^{bc}	2.4 ± 1.0^{e}	2.7 ± 1.1^{de}

[a]Definitions for the various characteristics are given in Appendix Tables 1 and 2.

[b,c,d,e]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

characteristics are very similar to those reported by this panel in the previous study (Table 17). This study incorporated an addition (size of chewed particles) and a deletion (particles) by the panel from the previous study. However, size of chewed particles did not differ among the various head sizes. Values for masticatory properties between the head sizes are very similar to those of the previous study. This either means that the panel was quite accurate with these products from two different processing times or that the two processing times produced steaks with very similar characteristics or both.

The effects of the two serving temperatures are given in Table 20 for texture profile panel results. Only one characteristic (number of chews) was affected by the two temperatures. This indicates that a wide fluctuation in sample temperature is incapable of influencing texture results. This knowledge certainly assists in being able to evaluate the maximum number of samples in a given period of time. Only two characteristics from the texture profiling were affected by the interaction of flake size and serving temperature.

This study also saw the inclusion of a fragmentation system by the panel following two chews. It was felt that this perhaps would give a better idea of the detailed textural properties of the steaks. As flake size decreased, the incidence of the samples being able to be completely sheared, decreased (Table 21). Also, the occurrence of a chunky, but incomplete separation decreased. In terms of breakdown during early mastication, these two fragementation categories seem to explain what actually is happening. Ground beef steaks seem to possess complete shearing and crumbly separation characteristics. Serving temperature did not affect fragmentation values to any great extent with the exception of

Table 20. Effects of sample serving temperature on texture profile panel scores.

Characteristic[a]	Serving temperature: Hot	Serving temperature: Warm
Visual		
Smoothness	8.4 ± 1.8	8.6 ± 2.4
Fibrousness	7.3 ± 1.9	6.1 ± 2.0
Partial compression		
Impression	5.4 ± 2.7	5.9 ± 2.3
First bite		
Hardness	6.6 ± 2.2	6.3 ± 1.7
Cohesiveness	7.4 ± 2.0	7.4 ± 1.9
Density	8.2 ± 1.7	7.9 ± 1.6
Uniformity	8.4 ± 2.1	9.5 ± 2.0
Mastication		
Juiciness	6.8 ± 1.5	6.0 ± 1.7
Size of chewed particles	2.7 ± 1.4	2.8 ± 1.7
Cohesiveness of mass--15 chews	7.0 ± 1.8	7.0 ± 1.1
Cohesiveness of mass--25 chews	6.9 ± 2.0	7.2 ± 1.5
Coarseness of mass--15 chews	7.8 ± 2.1	7.4 ± 1.5
Coarseness of mass--25 chews	6.0 ± 2.2	5.5 ± 1.6
Uniformity of mass	9.1 ± 1.6	9.3 ± 1.6
Gristle	2.6 ± 1.5	2.3 ± 1.7
Webbed tissue	3.0 ± 1.6	3.1 ± 1.6
Number of chews	57.9 ± 8.1[c]	61.2 ± 12.9[b]
After swallow		
Tooth pack	2.1 ± 1.1	2.0 ± .94
Mouth coating	3.5 ± 1.1	3.2 ± 1.9

[a]Definitions for the various characteristics are given in Appendix Tables 1 and 2.

[b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 21. Frequency of fragmentation categories in restructured beef steaks according to Comitrol head size.

	Comitrol head size				
Fragmentation category[a]	1610	750A	750B	060	Ground beef
Complete shearing	7.1	26.3	32.7	42.1	34.3
Complete crumbly separation	1.8	0.0	1.8	2.6	57.1
Compacts along shear line	1.8	0.0	1.8	5.3	2.9
Chunky and complete separation	17.9	5.3	21.8	13.2	2.9
Chunky, but incomplete separation	55.4	31.6	10.9	2.6	0.0
Layered separation	16.1	36.8	29.1	34.2	2.9
Other	0.0	0.0	1.8	0.0	0.0

[a]Values are percentage frequencies of sample evaluations within a Comitrol head size that were classified into the fragmentation categories.

more complete shearing and less chunky separation for warm vs hot samples (Table 22).

Interaction effects of head size and serving temperature are given in Table 23. With both extremes of head sizes (1610, 060) the hot samples displayed more distortion than the warm samples. The opposite situation was true for 750B steaks. In terms of moisture release, steaks made from large flake size particles had higher values when samples were served warm, while the hot samples gave the higher values for small flake size samples.

Both Instron values were involved in a significant ($P<0.05$) interaction of head size and serving temperature (Table 24). Generally, the higher shear force values and Newtons were obtained with the larger particle size. The interaction seems to center on how the two 750 products (A,B) reacted (opposite) to serving temperatures. It is of interest to note that within the 750 products, serving temperature did not affect texture profile panel characteristics.

Smaller particle size steaks yielded higher cooking losses (Table 25). Flake size has previously been found to have very little effect on cooking losses (Durland, et al., 1982, Seideman, et al., 1982ab). Serving temperature also affected cooking loss; however, this should be evaluated as total loss since the higher losses for warm steaks are probably due to evaporative and drip losses during cooling to room temperature.

Conclusions

Restructured beef steaks processed from large flake sizes continued to be rated as more fibrous, more uniform on first bite, less cohesiveness after 15 and 25 chews, more uniform in chewed mass and possessive of less

Table 22. Frequency of fragmentation categories in restructured beef steaks according to sample temperature when served.

Fragmentation category[a]	Serving temperature: Hot	Serving temperature: Warm
Complete shearing	24.3	33.9
Complete crumbly separation	11.1	11.9
Compacts along shear line	3.5	0.0
Chunky and complete separation	14.6	13.6
Chunky, but incomplete separation	25.0	13.6
Layered separation	20.8	27.1
Other	0.7	0.0

[a]Values are percentage frequencies of sample evaluations within a serving temperature that were classified into the fragmentation categories.

Table 23. Interaction effect of Comitrol head size and serving temperature on visual distortion and first bite moisture release scores from texture profile panel evaluations.

Variable	Distortion[a]	Moisture release[a]
1610--hot	7.4 ± 2.6	7.5 ± 2.5
1610--warm	5.2 ± 1.6	8.1 ± 1.7
750A--hot	8.1 ± 1.2	4.3 ± 1.6
750A--warm	8.1 ± 1.2	5.4 ± 1.5
750B--hot	8.2 ± 1.7	6.6 ± 2.0
750B--warm	10.4 ± 1.7	5.1 ± 2.1
060--hot	9.2 ± 2.1	5.2 ± 3.0
060--warm	6.4 ± 1.8	3.5 ± 1.9
ground beef--hot	3.2 ± 1.2	3.4 ± 1.5
ground beef--warm	3.5 ± 1.7	2.8 ± 1.6

[a]Distortion and moisture release scores were affected by the significant ($P < 0.05$) interaction of Comitrol head size and serving temperatures.

Table 24. Interaction effect of Comitrol head size and serving temperature on Instron values.[a]

Variable	Maximum shear force, kg	Newtons cm^2
1610--hot	23.8 ± 1.8	13.0 ± 0.2
1610--warm	23.5 ± 5.7	11.5 ± 2.6
750A--hot	20.6 ± 1.8	11.2 ± 1.0
750A--warm	7.8 ± 0.6	4.5 ± 1.1
750B--hot	16.8 ± 0.1	8.3 ± 0.1
750B--warm	20.8 ± 4.1	10.8 ± 1.1
060--hot	16.0 ± 0.4	9.3 ± 0.5
060--warm	15.4 ± 2.8	9.7 ± 1.2
Ground beef--hot	15.3 ± 0.2	8.3 ± 0.2
Ground beef--warm	10.3 ± 0.5	5.8 ± 0.1

[a]Both Instron values were significantly affected by the significant ($P < 0.05$) interaction of Comitrol head size and serving temperature.

Table 25. Effects of Comitrol head size and serving temperature on cooking loss.

Variable	Cooking loss, %
Comitrol head size	
1610	19.7 ± 3.1^{b}
750A	24.5 ± 3.7^{ab}
750B	19.6 ± 2.5^{b}
060	29.6 ± 3.9^{a}
Ground beef	28.7 ± 4.4^{a}
Serving temperature	
Hot	22.6 ± 3.5^{a}
Warm	26.3 ± 3.7^{b}

[a,b]Means in the same column within head size and temperature bearing different superscripts are significantly ($P < 0.05$) different.

connective tissue. Large particle steaks had less complete shearing with more chunky separation during chewing. Serving temperature seemed to exert its greatest affects on visual distortion and Instron values for the two 750 head size products.

USE OF WEIGHTS ON STEAKS AND FOIL AROUND GRILLS DURING COOKING ON CHARACTERISTICS OF RESTRUCTURED BEEF STEAKS VARYING IN FLAKE SIZE

Introduction

It was quite apparent by now that distortion was a major problem associated with restructured beef steaks. The problem seemed at this point to be more prevalent in steaks made from smaller particles. This might be construed to mean a more complete extraction of salt soluble protein which thus formed more of a crust during cooking. This crust might lead to more swelling, puffing, etc. with no place for steam or juices to go in the central part of the steaks. It is possible that this distortion is contributing to the considerable variation in certain textural properties.

Materials and Methods

Restructured beef steaks were made at Natick Laboratories using the 1610, 750 and 060 heads as previously described. The five cooking procedures were as follows: (1) steaks placed in cooking pouches and cooked in a 70 C water bath, (2) broiling steaks on foil-on Farberware grills with 557 g weights on steaks, (3) broiling steaks on foil-off Farberware grills with 557 g weights on steaks, (4) broiling steaks on a foil-off Farberware grills--no weights, and (5) broiling steaks on a foil-off Farberware grills--no weights. All steaks were cooked to a final internal temperature of 70 C. Where the final internal temperature did not match the cooked appearance, the thermocouples were either reinserted or relocated and either additional temperature measurements and/or longer

cooking were required. Steaks cooked with weights were turned more frequently (7 vs 12 min). The weights were kept on the steaks for the total duration of the cooking cycle. Steaks cooked in the water bath at 70 C were placed in sealed bags as was done in a previous study.

Results and Discussion

Results of the texture profile evaluations according to the cooking procedures are given in Table 26. Water bath cooking produced the least distortion (as was found previously) but the differences were not significant ($P>0.05$) from cooking procedures that employed the weights. Water bath cooking also produced the least evidence of fibrousness, springiness and first bite hardness. The use of the weights apparently kept some of the juices from escaping during cooking as moisture release values were lower for weight on vs weight off cooked steaks. First bite uniformity was highest for steaks cooked in the water bath; which was probably due to the absence of crust formation.

Most mastication properties were not affected by the cooking procedures. For steaks cooked without weights, those cooked on broilers with foil had lower juiciness scores, required a greater number of chews and produced more mouth coating than steaks cooked without foil.

Water bath cooking produced a higher frequency of shears cleanly than the other cooking methods. This was probably due to the absence of crust on steaks cooked in the water bath. Steaks from the water bath cooking method were also rated as compacting along the shearline to a higher degree than steaks from the other methods. It would appear that the use of weights during cooking reduced the incidence of chunky separation, probably as a result of preventing some swelling.

Table 26. Effects of cooking method on texture profile characteristics of restructured steaks.

Characteristic[b]	Cooking method[a]				
	Water bath	Weight on foil on	Weight on foil off	Weight off foil on	Weight off foil off
Visual					
Distortion	5.7 ± 1.7^{d}	6.3 ± 0.9^{cd}	6.5 ± 1.7^{cd}	6.9 ± 1.3^{c}	6.7 ± 1.4^{c}
Fibrousness	5.8 ± 2.3^{d}	6.8 ± 2.3^{c}	7.2 ± 1.7^{c}	7.3 ± 1.0^{c}	7.5 ± 1.5^{c}
Partial Compression					
Springiness	9.3 ± 2.1^{d}	10.5 ± 1.8^{c}	10.3 ± 1.7^{c}	10.7 ± 1.1^{c}	10.3 ± 1.6^{c}
First Bite					
Hardness	5.5 ± 1.7^{e}	7.5 ± 1.9^{d}	7.9 ± 1.9^{d}	9.3 ± 1.6^{c}	7.4 ± 2.2^{d}
Cohesiveness	8.7 ± 2.1	9.2 ± 1.3	9.4 ± 1.8	9.5 ± 2.2	9.0 ± 2.0
Moisture Release	6.2 ± 1.6^{de}	6.5 ± 1.5^{d}	6.7 ± 2.0^{d}	5.7 ± 1.1^{e}	7.9 ± 0.9^{c}
Uniformity	11.0 ± 1.2^{c}	9.9 ± 1.6^{d}	8.7 ± 2.0^{e}	8.7 ± 2.4^{e}	8.8 ± 2.4^{e}
Mastication					
Juiciness	7.4 ± 1.6^{d}	7.9 ± 1.1^{cd}	7.4 ± 1.0^{d}	6.7 ± 1.3^{e}	8.4 ± 0.7^{c}
Cohesiveness of mass at 10 chews	7.8 ± 2.8	7.7 ± 1.6	7.6 ± 2.0	7.3 ± 2.4	7.9 ± 1.7
Cohesiveness of mass at 25 chews	8.0 ± 2.8	8.0 ± 2.3	8.6 ± 1.8	8.3 ± 2.4	9.4 ± 1.6
Gristle	3.8 ± 2.5	3.2 ± 2.0	3.7 ± 2.3	3.6 ± 2.4	3.3 ± 1.5
Webbed tissue	4.3 ± 2.6	4.0 ± 1.7	4.1 ± 1.7	3.8 ± 1.4	4.4 ± 1.2
Size of chewed particle	9.6 ± 1.9	9.3 ± 2.2	9.8 ± 1.8	9.3 ± 2.2	9.1 ± 1.4
Uniformity of mass	10.9 ± 2.4	10.4 ± 2.0	9.3 ± 2.1	10.2 ± 2.5	10.4 ± 1.6
Number of chews	61.2 ± 10.9^{d}	62.8 ± 13.3^{d}	67.6 ± 8.9^{cd}	71.4 ± 14.6^{c}	64.7 ± 5.8^{d}
After Swallow					
Tooth pack	2.6 ± 1.2^{d}	3.6 ± 1.8^{c}	3.9 ± 1.8^{c}	4.0 ± 1.7^{c}	3.4 ± 1.1^{cd}
Mouth coating	5.5 ± 1.5^{c}	4.9 ± 0.9^{cd}	5.1 ± 1.6^{cd}	4.4 ± 1.1^{d}	5.6 ± 0.9^{c}

[a]Cooking methods with weights and foil were performed on Farberware grills.

[b]Definitions for the various characteristics are given in Appendix Table 2.

[c,d,e]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 27. Frequency of fragmentation categories in restructured beef steaks according to cooking method.

Fragmentation category	Cooking method				
	Water bath	Weight on foil on	Weight on foil off	Weight off foil on	Weight off foil off
Shears cleanly	44.7	40.0	29.0	26.8	34.2
Crumbly separation	2.6	2.5	0.0	2.4	0.0
Compacts along shear line	23.7	15.0	18.4	14.6	18.4
Chunky separation--complete	5.3	2.5	7.9	14.6	10.5
Chunky separation--incomplete	13.2	15.0	15.8	12.2	21.0
Layered separation	2.6	2.5	15.8	12.2	0.0
Other	7.9	22.5	13.2	17.1	15.8

Values for steaks of the different flake sizes (Table 28) do not appreciably differ from those of earlier studies in this report. The biggest and most consistent differences were found for fibrousness, first bite hardness, uniformity of first bite, juiciness, cohesiveness of mass, gristle, webbed tissue, size of chewed pieces, uniformity of mass and tooth pack. The major and consistent differences between flake sizes for fragmentation categories appeared to be that as flake size decreased, the presence of more clean shearing increased. Large flake size steaks were also classified as having more chunky separation than medium and small flake size steaks (Table 29).

The effects of the interaction of flake size with cooking method is given in Table 30. There was a tendency for shear force to be highest for large flake size steaks, lowest for small flake size steaks and intermediate for medium flake size steaks, regardless of cooking method. However, for water bath, weight on-foil off and weight off-foil on steaks, the differences between medium and small flake size steaks was very minimal. There was a similar tendency for Newtons, except that the differences between medium and small flake size steaks were apparent only for steaks cooked with both weights and foil off. Cooking yields followed no particular pattern respective to cooking methods and flake size.

Conclusions

The use of flat weights on steaks and foil on Farberware grills was basically ineffective in reducing distortion and variability in other textural parameters.

Table 28. Effects of flake size on texture profile characteristics of restructured beef steaks.

Characteristics[a]	Flake size: Large	Medium	Small
Visual			
Distortion	5.3 ± 1.3^{d}	7.3 ± 1.2^{b}	6.7 ± 1.3^{c}
Fibrousness	9.5 ± 1.6^{b}	6.9 ± 1.7^{c}	4.2 ± 0.8^{d}
Partial Compression			
Springiness	10.0 ± 1.6^{c}	9.8 ± 1.6^{c}	10.9 ± 1.6^{b}
First Bite			
Hardness	8.9 ± 1.9^{b}	7.4 ± 1.9^{c}	6.0 ± 1.6^{d}
Cohesiveness	9.4 ± 1.9	9.1 ± 1.9	9.0 ± 1.6
Moisture release	7.0 ± 1.7^{b}	6.7 ± 1.7^{b}	6.0 ± 1.4^{c}
Uniformity	6.3 ± 2.2^{d}	10.4 ± 1.7^{c}	11.8 ± 1.9^{b}
Mastication			
Juiciness	8.2 ± 1.3^{b}	7.3 ± 1.4^{c}	7.1 ± 0.9^{d}
Cohesiveness of mass at 10 chews	8.8 ± 1.9^{b}	7.7 ± 2.1^{c}	6.4 ± 1.6^{d}
Cohesiveness of mass at 25 chews	9.6 ± 1.9^{b}	8.5 ± 1.6^{c}	7.1 ± 2.0^{d}
Gristle	7.5 ± 2.4^{b}	2.7 ± 1.8^{c}	0.2 ± 0.2^{d}
Webbed tissue	7.4 ± 2.0^{b}	3.8 ± 2.0^{c}	0.9 ± 0.5^{d}
Size of chewed particles	10.6 ± 1.7^{b}	9.3 ± 2.0^{c}	8.3 ± 2.0^{d}
Uniformity of mass	7.5 ± 2.7^{d}	10.9 ± 1.8^{c}	12.5 ± 1.5^{b}
Number of chews	73.4 ± 11.8^{b}	63.0 ± 11.4^{c}	60.0 ± 11.1^{c}
After Swallow			
Tooth pack	4.7 ± 1.8^{b}	3.2 ± 1.4^{c}	2.6 ± 1.2^{d}
Mouth coating	5.9 ± 1.3^{b}	1.3 ± 5.0^{c}	4.3 ± 1.4^{d}

[a]Definitions for the various characteristics are given in Appendix Table 2.

[b,c,d]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 29. Frequency of fragmentation categories in restructured beef steaks according to flake size.

	Flake size		
Fragmentation category	Large	Medium	Small
Shears cleanly	17.4	37.3	52.5
Crumbly separation	0.0	4.5	0.0
Compacts along shear line	21.7	11.9	20.3
Chunky separation--complete	13.0	9.0	1.7
Chunky separation--incomplete	34.8	9.0	0.0
Layered separation	1.4	10.4	8.5
Other	11.6	17.9	17.0

Table 30. Effects of flake size and cooking method on Instron values and cooking yield of restructured steak.

		Cooking method				
Value	Flake size	Water bath	Weight on foil on	Weight on foil off	Weight off foil on	Weight off foil off
Shear force, kg.	Large	19.2	20.7	17.3	21.6	18.4
	Medium	10.9	12.4	11.6	14.1	14.3
	Small	9.3	9.8	10.7	14.6	11.6
Newton/cm^2	Large	19.9	22.3	17.6	21.0	18.4
	Medium	10.0	11.6	11.5	14.6	13.9
	Small	9.1	10.8	10.8	15.0	10.9
Cooking yield, %	Large	82.6	72.6	75.1	71.6	75.2
	Medium	86.2	76.3	81.8	71.7	77.9
	Small	81.1	76.4	79.6	69.7	70.1

STUDIES EVALUATING FAT LEVEL, CONNECTIVE TISSUE LEVEL, COMITROL HEAD CONFIGURATION AND SOY ADDITION EFFECTS ON RESTRUCTURED STEAKS

Introduction

These series of studies again examined various factors during restructured steak processing that conceivably could affect the end-product. Fat levels have been thoroughly investigated with ground beef, but have received only minor attention with restructured steaks. Mandigo (1982) indicated that 20 to 25% fat produced desirable palatability in flaked steaks, but 10 to 15% fat produced preferred palatability in sectioned and formed beef steaks. Cross and Stanfield (1976) found consumers preferred restructured steaks with 30% fat and added salt vs restructured steaks with 20% fat and no salt. Connective tissue amount has been identified as an important factor affecting textural attributes of restructured steaks. Previous studies have not been performed to create broad differences in connective tissue levels while standardizing all other processing variables of this report.

Studies in this report of flake size or Comitrol head size have been shown to greatly and consistently affect certain textural properties. However, configuration of flake particles of the same size and sharpness of the Comitrol heads have not been compared as related to end product attributes. Addition of soy and other plant proteins have received some attention. Cardello, et al. (1983) found 1.0% soy addition to assist in meat binding, while providing some improvement in coarseness and springiness.

Hand, et al. (1981) found that replacement of 13% by weight of meat with isolated soy protein failed to produce any changes in textural properties.

Materials and Methods

Processing steps and equipment were basically those identified in previous studies of this report. USDA Yield Grade 2 and 3 square-cut chucks were used as the beef for the steaks. In the first study, four distinct levels of fat (10, 14, 18, 22%) were chosen. Final chemical analyses of the steaks indicated that the steaks, according to treatment, yielded the following fat levels: 10% = 9.8%, 14% = 13.7%, 18% = 17.8%, 22% = 22.4%. The Comitrol 750 head was used for flaking purposes.

In the study comparing various levels of connective tissue, the three levels (high, intermediate, low) were achieved through trimming procedures. Extensive trimming of connective tissue layers or boneless chucks was performed for the low level. The connective tissue removed was added to additional boneless chucks which received no trimming to yield raw materials for the high level of connective tissue. The intermediate level was achieved by removing only the very heavy pieces of connective tissue (i.e. protruding tendons).

Comitrol recently has manufactured a new 750 type flaking head (all flake particles = 1.9 cm long) which was compared to the standard and perhaps duller head (2/3 of flake particles 1.9 cm long and 1/3 of flake particles = 0.95 cm long). USDA Yield Grade 2 and 3 square-cut chucks were used for this study. With flaked meat from the new 750 head, 1% by weight of textured soy protein was added and this treatment was compared to the flaked steaks manufactured with this head that did not contain soy.

Steaks for these studies were cooked on the Farberware open hearth broilers. Steaks were cooked on one side for 12 min, thermocouples were inserted and they were turned and cooking continued until 70° C internal temperature was reached. Steaks were turned as needed for even browning.

Steak sections 5.4 cm wide were sheared across the 5.4 cm wide section every 0.9 cm into the section. Texture profile panel procedures were as previously described.

Results and Discussion

Restructured steaks processed to have the two highest fat levels had more visual distortion following cooking than steaks processed to have the two lowest fat levels (Table 31). Surprisingly, steaks made to have 22% fat were assessed as having the most fibrous appearance. Springiness, hardness and cohesiveness values were not affected by fat levels. The panelists found less uniformity of first bite for steaks made to have 22% fat compared to steaks processed to have 10 and 14% fat. Steaks processed to have 18 and 22% fat yielded higher ($P<0.05$) moisture release values during first bite than steaks processed to have 10 and 14% fat. Cross and Stanfield (1976) found no differences in consumer response to juiciness of restructured steaks with 30% fat vs 20% fat. Juiciness scores in our study showed a similar trend to moisture release values.

The amount of gristle detected by the panelists following 10 chews was higher for restructured steaks with 22% fat compared to the other three fat levels. Since fat deposits are often in close proximity to connective tissue membranes, it is conceivable that in the trimming of beef materials to reduce fat, some connective tissue is also removed. The amount of webbed tissue evaluated at the completion of mastication also

Table 31. Effects of fat level on texture profile panel scores.

Characteristics[a]	Fat level, %			
	10	14	18	22
Visual				
Distortion	4.0 ± 1.1^c	4.1 ± 1.2^c	5.8 ± 2.6^b	5.2 ± 1.5^b
Fibrousness	6.9 ± 1.9^c	6.3 ± 1.9^c	6.3 ± 1.3^c	7.8 ± 1.6^b
Partial compression				
Springiness	9.3 ± 1.2	9.4 ± 0.7	8.8 ± 1.3	9.0 ± 2.7
First bite				
Hardness	6.8 ± 1.7	8.1 ± 0.7	7.2 ± 1.0	8.0 ± 2.0
Cohesiveness	9.4 ± 0.9	9.2 ± 1.3	8.6 ± 1.5	8.9 ± 1.3
Uniformity	10.7 ± 1.5^b	11.0 ± 1.9^b	$10.0 \pm 1.3^{b,c}$	9.2 ± 1.8^c
Moisture release	6.0 ± 1.9^c	5.5 ± 0.9^c	7.1 ± 1.2^b	7.5 ± 0.9^b
Mastication				
Juiciness	6.5 ± 0.5^c	6.4 ± 1.3^c	7.9 ± 0.9^b	8.5 ± 1.1^b
Size of chewed particles	9.3 ± 2.0	9.5 ± 1.2	8.9 ± 1.0	8.8 ± 1.8
Gristle	3.6 ± 2.0^c	3.2 ± 2.8^c	2.7 ± 1.1^c	5.4 ± 2.5^b
Cohesiveness of mass	8.9 ± 1.6	9.4 ± 1.7	8.2 ± 2.2	9.6 ± 1.9
Uniformity of mass	10.9 ± 1.3	10.6 ± 2.1	10.9 ± 1.3	9.4 ± 2.8
Webbed tissue	3.6 ± 2.4^c	4.7 ± 1.6^c	3.8 ± 1.5^c	6.5 ± 1.8^b
Number of chews	51.0 ± 14.1^c	$58.0 \pm 11.2^{b,c}$	$57.9 \pm 8.7^{b,c}$	64.1 ± 11.0^b
After swallow				
Tooth pack	3.5 ± 0.8	3.4 ± 1.8	3.1 ± 1.2	3.4 ± 1.0
Mouth coating	4.4 ± 1.6^c	4.2 ± 1.3^c	5.1 ± 1.2^b	5.9 ± 1.2^b

[a]Definitions for the various characteristics are given in Appendix Tables 2 and 3.

[b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

indicated more connective tissue in restructured steaks processed to have 22% fat compared to restructured steaks processed to have 10% fat. This increased connective tissue in the 22% fat steaks may also be responsible for the greater number of chews reported by the panelists. In terms of overall tenderness, Cross and Stanfield (1976) found consumer preferences to be higher for flaked and formed beef steaks possessing 30% fat vs flaked or formed beef steaks with 20% fat. Mouthcoating was highest in samples from the two highest fat levels.

There was some tendency for steaks with reduced levels of fat to shear more cleanly and completely (Table 32). When incomplete shearing was detected, the tendency for this to be the result of surface crust was reduced in the steaks containing 22% fat. There was some evidence of both complete and incomplete chunky separation to increase with higher levels of fat.

There were no differences in cooking times, although there was a trend for shorter cooking times as fat levels increased (Table 33). While steaks formulated to have higher fat levels exhibited a greater increase in steak thickness than steaks made to have less fat, these differences were nonsignificant ($P>0.05$). Steaks made to have 22% fat underwent the greatest decrease in steak diameter as a result of cooking. The texture profile panel also found that steaks containing higher levels of fat had more visual distortion. Instron maximum shear force values did not differ among the fat levels. However, when the Instron shear force values were expressed as Newtons (thus taking into consideration steak thickness), steaks having 18% fat had lower Newton values than 10 and 14% fat steaks and steaks with 22% fat had lower Newton values than those containing 14 and 18% fat. These results illustrate the importance of including sample

Table 32. Frequency of fragmentation categories in restructured beef steaks according to fat level.

	Fat level, %			
Fragmentation category[a]	10	14	18	22
Complete shearing	48.3	30.6	17.1	26.5
Incomplete shearing--threads	31.0	19.4	22.9	29.4
Incomplete shearing--crust	17.2	30.6	22.9	5.9
Complete crumbly separation	0.0	0.0	0.0	0.0
Incomplete crumbly separation--threads	0.0	0.0	0.0	0.0
Incomplete crumbly separation--crust	0.0	0.0	0.0	0.0
Compacts along shear line	0.0	8.3	0.0	8.8
Chunky and complete separation	0.0	0.0	2.9	8.8
Incomplete chunky separation--threads	3.4	5.6	11.4	11.8
Incomplete chunky separation--crust	0.0	2.8	8.6	5.9
Layered separation	0.0	2.8	11.4	0.0
Other	0.0	0.0	2.8	2.9

[a]Values are percentage frequencies of sample evaluations within a fat level that were classified into the fragmentation categories.

Table 33. Effects of fat level on cooking properties and Instron values for restructured beef steaks.

Characteristic	Fat level, % 10	14	18	22
Cooking properties				
Degree of doneness score	3.6 ± 1.1	$3.2 \pm .76$	$3.3 \pm .74$	$3.4 \pm .53$
Cooking time, min	28.6 ± 1.6	28.4 ± 1.5	$27.2 \pm .89$	26.1 ± 2.7
Cooking loss, %	23.2 ± 4.2	29.1 ± 4.1	25.9 ± 3.4	27.2 ± 2.7
Change in steak thickness from raw to cooked, %	1.2 ± 11.2	-2.3 ± 7.2	5.5 ± 12.9	3.1 ± 9.8
Change in steak diameter from raw to cooked, %	-13.2 ± 2.6^{b}	-13.8 ± 4.4^{b}	-14.7 ± 5.4^{b}	-19.8 ± 2.0^{a}
Instron				
Maximum shear force, kg	18.6 ± 2.2	18.5 ± 2.6	16.1 ± 3.5	17.3 ± 1.4
Newtons/cm^2	21.5 ± 2.7^{ab}	22.6 ± 3.3^{a}	17.1 ± 2.2^{c}	19.5 ± 2.2^{bc}

^{a,b,c}Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

thickness when measuring shear properties in a product such as restructured steaks which frequently have a high degree of distortion and a lack of uniformity in thickness. Cross and Stanfield (1976) found that consumers detected greater ease in cutting flaked and formed steaks possessing 30% fat vs 20% fat.

Visual observations for distortion and fibrousness indicate that removal of connective tissue (intermediate and low) resulted in less distortion and fibrousness (Table 34). The addition of extra connective tissue to trimmings that received no trimming for connective tissue (high) produced greater hardness and cohesiveness and less uniformity during first bite procedures than intermediate and low connective tissue samples. During mastication, the texture profile panel was able to perceive logical differences between gristle among all three levels and found the high steaks to have more webbed tissue than the low steaks. Steaks having the greatest removal of connective tissue (small) were rated as more uniform than high and intermediate level steaks. The major difference in fragmentation values (Table 35) was the almost absence of incomplete shearing due to crust for high connective tissue steaks compared to intermediate and low connective tissue steaks.

Cooking properties were unaffected ($P>0.05$) by connective tissue levels (Table 36). Steaks with low and intermediate levels of connective tissue had both lower shear force and Newton values.

Distortion values were slightly reduced in a comparison of a new vs old 750 Comitrol head (Table 37). First bite uniformity was substantially higher in the old 750 steaks. The old 750 head appeared more effective in reducing the levels of detectable gristle and webbed tissue; perhaps due to 1/3 of the flakes being smaller than in the new 750 head.

Table 34. Effects of connective tissue levels on texture profile panel scores.

Characteristic[a]	Connective tissue level		
	High	Intermediate	Low
Visual			
Distortion	5.6 ± 1.2[b]	4.2 ± 1.6[c]	3.7 ± 0.5[c]
Fibrousness	7.2 ± 1.7[b]	5.3 ± 1.6[c]	6.5 ± 1.1[bc]
Partial compression			
Springiness	10.4 ± 1.6	8.8 ± 2.2	8.8 ± 1.1
First bite			
Hardness	8.4 ± 1.5[b]	6.8 ± 1.1[c]	6.5 ± 1.7[c]
Cohesiveness	9.8 ± 1.9[b]	8.4 ± 1.4[c]	8.5 ± 2.3[c]
Uniformity	8.1 ± 2.5[c]	10.3 ± 1.7[b]	11.2 ± 1.3[b]
Moisture release	5.3 ± 0.8	6.9 ± 0.7	6.4 ± 1.1
Mastication			
Juiciness	6.8 ± 1.6	7.3 ± 1.0	6.8 ± 1.7
Size of chewed particles	9.5 ± 1.9[b]	9.2 ± 1.1[b]	8.0 ± 2.1[c]
Gristle	6.3 ± 1.6[b]	4.0 ± 1.3[c]	2.0 ± 1.1[d]
Cohesiveness of mass	7.8 ± 2.5	7.6 ± 2.1	8.5 ± 2.7
Uniformity of mass	8.2 ± 2.2[c]	8.9 ± 2.5[c]	11.8 ± 1.0[b]
Webbed tissue	6.0 ± 1.5[b]	4.8 ± 2.2[bc]	2.8 ± 2.6[c]
Number of chews	61.6 ± 12.0	58.5 ± 11.1	54.1 ± 9.8
After swallow			
Tooth pack	4.0 ± 1.4	3.4 ± 1.0	3.2 ± 1.7
Mouth coating	5.2 ± 1.2	5.1 ± 1.3	4.6 ± 1.5

[a]Definitions for the various characteristics are given in Appendix Tables 2 and 3.

[b,c,d]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 35. Frequency of fragmentation categories in restructured beef steaks according to connective tissue levels.

	Connective tissue level		
Fragmentation category[a]	High	Intermediate	Low
Complete shearing	31.4	31.4	37.5
Incomplete shearing--threads	31.4	28.6	25.0
Incomplete shearing--crust	2.9	20.0	21.9
Complete crumbly separation	0.0	0.0	0.0
Incomplete crumbly separation--threads	2.9	0.0	3.1
Incomplete crumbly separation--crust	0.0	0.0	0.0
Compacts along shear line	5.7	0.0	3.1
Chunky and complete separation	2.9	0.0	6.2
Incomplete chunky separation--threads	8.6	8.6	0.0
Incomplete chunky separation--crust	8.6	0.0	0.0
Layered separation	5.7	8.6	3.1
Other	0.0	2.9	0.0

[a]Values are percentage frequencies of sample evaluations within connective tissue levels that were classified into the fragmentation categories.

Table 36. Effects of connective tissue levels on cooking properties and Instron values.

	Connective tissue level		
Characteristic	High	Intermediate	Low
<u>Cooking properties</u>			
Degree of doneness score	3.3 ± .53	3.4 ± .35	3.2 ± .74
Cooking time, min	26.0 ± .46	24.2 ± .92	26.6 ± .76
Cooking loss, %	24.9 ± 3.2	24.2 ± 2.1	27.7 ± 3.7
Change in steak thickness from raw to cooked, %	-1.9 ± 7.5	0.3 ± 3.5	2.5 ± 4.8
Change in steak diameter from raw to cooked, %	-18.3 ± 2.9	-17.9 ± 3.8	-19.1 ± 2.8
<u>Instron</u>			
Maximum shear force, kg	21.7 ± 3.2[b]	16.0 ± 1.1[a]	13.7 ± 1.8[a]
Newtons/cm^2	24.8 ± 3.8[b]	18.6 ± 1.4[a]	16.1 ± 2.3[a]

[a,b]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 37. Comparison of new style Comitrol 750 head with old style Comitrol 750 head for texture profile panel scores.

Characteristics[a]	New 750 head	Old 750 head
Visual		
Distortion	5.2 ± 1.5^c	5.8 ± 2.5^b
Fibrousness	7.8 ± 1.6	6.6 ± 1.3
Partial Compression		
Springiness	9.0 ± 2.7	9.5 ± 1.5
First Bite		
Hardness	8.0 ± 2.0	6.6 ± 2.5
Cohesiveness	8.9 ± 1.3	8.6 ± 1.2
Uniformity	9.2 ± 1.8^c	11.3 ± 1.7^b
Moisture release	7.5 ± 0.9	6.9 ± 2.4
Mastication		
Juiciness	8.5 ± 1.1^b	7.5 ± 1.2^c
Size of chewed particles	8.8 ± 1.8	9.0 ± 1.2
Gristle	5.4 ± 2.5^b	2.6 ± 2.5^c
Cohesiveness of mass	9.6 ± 1.9^b	6.8 ± 0.9^c
Uniformity of mass	9.4 ± 2.8	10.2 ± 2.2
Webbed tissue	6.5 ± 1.8^b	3.0 ± 1.3^c
Number of chews	64.1 ± 11.0	60.0 ± 3.4
After Swallow		
Tooth pack	3.4 ± 1.0	3.2 ± 1.3
Mouth coating	5.9 ± 1.2	5.8 ± 2.2

[a]Definitions for the various characteristics are given in Appendix Tables 2 and 3.

[b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Restructured steaks manufactured from beef flaked through the old 750 head were classified as having more complete shearing, but also more incomplete shearing with crust (Table 38). Product derived from flaked beef using the new 750 head was considered as more chunky (both complete and incomplete) compared to the old 750 head.

The new 750 head seemed to create more shrinkage of steak diameters compared to the old 750 head (Table 39). Higher shear force and Newton values were found in steaks from the new 750 vs old 750 head. From the texture panel data, only gristle, webbed tissue and cohesiveness during mastication paralleled this trend.

The addition of 1% soy to flaked meats for restructured steaks resulted in lower moisture release, juiciness and cohesiveness of mass ratings compared to nonsoy added product (Table 40). These differences in moisture release are opposite of those found by Cardello, et al. (1983) with a 1% soy addition in restructured steaks. Hand, et al. (1981) found no differences in palatability attributes of all meat restructured steaks vs those with a 13% replacement with isolated soy protein. Very little difference was noted in fragmentation values (Table 41) attributable to the addition of 1% soy.

Cooking times and losses were unaffected by soy addition (Table 42). Hand, et al. (1981) found no effect of 13% isolated soy protein replacement in cooking loss of restructured steaks. Steaks made from soy added trimmings had less steak diameter shrinkage and underwent a shrinkage rather than a swelling in steak thickness. Soy addition may be an effective means of reducing some of the distortion problems of restructured steaks. Shear force values were not different ($P>0.05$) as a result of soy addition, except when expressed as Newtons. In this case,

Table 38. Frequency of fragmentation categories in restructured beef steaks according to new vs. old Comitrol 750 head size.

Fragmentation category[a]	New 750 head	Old 750 head
Complete shearing	26.5	50.0
Incomplete shearing--threads	29.4	11.5
Incomplete shearing--crust	5.9	26.9
Complete crumbly separation	0.0	0.0
Incomplete crumbly separation--threads	0.0	0.0
Incomplete crumbly separation--crust	0.0	0.0
Compacts along shear line	8.8	0.0
Chunky and complete separation	8.8	0.0
Incomplete chunky separation--threads	11.8	0.0
Incomplete chunky separation--crust	5.9	3.8
Layered separation	0.0	3.8
Other	2.9	3.8

[a]Values are percentage frequencies of sample evaluations within new and old 750 heads that were classified into the fragmentation categories.

Table 39. Comparison of new style Comitrol 750 head with old style Comitrol 750 head for cooking properties and Instron values for restructured beef steaks.

Characteristic	New 750 head	Old 750 head
Cooking properties		
Degree of doneness score	3.3 $\pm$ .53	3.1 $\pm$ .52
Cooking time, min	26.1 $\pm$ 2.7	28.0 $\pm$ .88
Cooking loss, %	27.2 $\pm$ 2.7	25.6 $\pm$ 4.5
Change in steak thickness from raw to cooked, %	3.1 $\pm$ 9.8	4.7 $\pm$ 9.9
Change in steak diameter from raw to cooked, %	-19.8 $\pm$ 2.0[a]	-16.0 $\pm$ 2.8[b]
Instron		
Maximum shear force, kg	17.3 $\pm$ 1.4[a]	12.5 $\pm$ 2.3[b]
Newtons/cm^2	19.5 $\pm$ 2.2[a]	13.9 $\pm$ 2.4[b]

[a,b]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 40. Effects of soy addition to restructured steaks on texture profile panel scores.

Characteristic[a]	1% soy	No soy
Visual		
Distortion	5.6	5.2 ± 1.5
Fibrousness	7.1	7.8 ± 1.6
Partial compression		
Springiness	9.5	9.0 ± 2.7
First bite		
Hardness	7.3	8.0 ± 2.0
Cohesiveness	9.5	8.9 ± 1.3
Uniformity	9.1	9.2 ± 1.8
Moisture release	4.9[c]	7.5 ± 0.9[b]
Mastication		
Juiciness	5.4[c]	8.5 ± 1.1[b]
Size of chewed particles	8.1	8.8 ± 1.8
Gristle	3.1	5.4 ± 2.5
Cohesiveness of mass	6.1[c]	9.6 ± 1.9[b]
Uniformity of mass	10.5	9.4 ± 2.8
Webbed tissue	5.0	6.5 ± 1.8
Number of chews	51.5	64.1 ± 11.0
After swallow		
Tooth pack	4.0	3.4 ± 1.0
Mouth coating	4.5	5.9 ± 1.2

[a]Definitions for the various characteristics are given in Appendix Tables 2 and 3.

[b,c,d]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 41. Frequency of fragmentation categories in restructured beef steaks according to soy addition.

Fragmentation category	Soy addition: 1% Added soy	Soy addition: No soy
Complete shearing	35.7	26.5
Incomplete shearing--threads	21.4	29.5
Incomplete shearing--crust	14.3	5.9
Complete crumbly separation	0.0	0.0
Incomplete crumbly separation--threads	0.0	0.0
Incomplete crumbly separation--crust	0.0	0.0
Compacts along shear line	14.3	8.8
Chunky and complete separation	7.1	8.8
Incomplete chunky separation--threads	7.1	11.8
Incomplete chunky separation--crust	0.0	5.9
Layered separation	0.0	0.0
Other	0.0	2.9

[a]Values are percentage frequencies of sample evaluations within soy additions that were classified into the fragmentation categories.

Table 42. Effects of soy addition to restructured steaks on cooking properties and Instron values.

Characteristic	1% Added soy	No soy
Cooking properties		
Degree of doneness score	3.5 ± .52	3.4 ± .53
Cooking time, min	28.4 ± 2.1	26.1 ± 2.7
Cooking loss, %	33.3 ± 3.7	33.4 ± 2.7
Change in steak thickness from raw to cooked, %	-7.8 ± 7.7[a]	3.1 ± 9.8[b]
Change in steak diameter from raw to cooked, %	-15.7 ± 4.3[b]	-19.8 ± 2.0[a]
Instron		
Maximum shear force, kg	18.2 ± 1.8	17.3 ± 1.4
Newtons/cm^2	22.5 ± 1.2[a]	19.5 ± 2.2[b]

[a,b]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

when taking into consideration the increased thickness of the nonsoy added steaks, they had lower Newton values than steaks with added soy. Hand, et al. (1981) found no changes in various Instron measurements as a result of a 13% addition of isolated soy protein.

Conclusions

Increased levels of fat were shown to increase detectable connective tissue, juiciness and mouthcoating. The increased fat caused more steak distortion which resulted in lower Newton values. Removal of connective tissue (or addition) can exert considerable influence on textural properties. Slight variations in the shape of 750 size flake particles (plus variations in blade dullness) can affect the ability to shear samples by teeth or mechanical blade. Flake particles produced with a dull blade resulted in lower shear values in restructured steaks; perhaps due to their inability to achieve satisfactory binding to each other. The addition of 1% soy produced a drying effect as perceived by a texture panel, but not through cooking losses. Less measurable configurational changes were detected as a result of the soy addition.

EFFECTS OF BLADE TENDERIZATION ON TEXTURE PROFILE PANEL, INSTRON AND COOKING VALUES

Introduction

In the last study prior to this one, it was apparent that either removal or addition of heavy types of connective tissue could affect textural properties. Numerous studies have utilized blade tenderization of raw materials intended for use in restructured meat products; however, few studies have compared the use vs nonuse of blade tenderization with restructured products. In one study where this was done (Booren, et al., 1981) no mention was made as to the exact effects of blade tenderization on textural properties of the restructured steaks.

The purpose of this study was to evaluate the commonly used 2 pass-through blade tenderization in comparison to no blade tenderization, plus an extensive 12 pass-through blade tenderization procedure.

Materials and Methods

USDA Choice Yield Grade 2 and 3 chucks were the raw material. Following trimming for heavy layers of connective tissue, protruding tendons, etc., some of the trimmings were subjected to mechanical blade tenderization. Part were subjected to 2 passes through the tenderizer while part were given 12 passes through the tenderizer. Processing of restructured steaks was as previously described using the Comitrol 750 head.

Steaks were cooked to 70° C as previously described and subjected to texture profile and Instron tests in the manner which has been previously established in this report.

Results and Discussion

Restructured steaks made from beef given 12 passes through the tenderizer were rated as having less micro distortion than steaks made from non-tenderized beef and beef given 2 passes through the tenderizer (Table 43). Uniformity of mass was higher and amount of gristle was less for the 12 passed-through product vs the other two treatments. None of the other texture panel values were affected by the blade tenderization procedures. It was certainly expected that blade tenderization would exert more of an effect, especially on connective tissue scores; however the connective tissue levels regardless of blade tenderization were quite low.

Fragmentation classification patterns (Table 44) showed a slight indication that 12 passes through the blade tenderizer resulted in some alteration of connective tissue. This was evident in the reduced frequency of incomplete shearing with treads for restructured steaks from trimmings given 12 passes through.

A more rare degree of doneness was found in restructured steaks made from 12 pass-through trimmings compared to steaks from 0 and 2 pass-through trimmings (Table 45). The use of blade tenderization (either 2 or 12X) reduced cooking losses. Steaks made from blade tenderized beef (both 2 and 12 passes) had more swelling than steaks made from beef not receiving blade tenderization. These trends were not evident to the texture profile panel. Restructured steaks made from 12 pass-through beef had lower shear force values than steaks made from non-tenderized beef. For Newtons, steaks of both levels of tenderization had lower values than non-tenderized steaks.

Table 43. Effects of blade tenderization on texture profile panel scores for restructured beef steaks.

Characteristic[a]	Number of passes through blade tenderizer: 0	2	12
Visual			
Macro distortion	4.0 ± 1.7	3.5 ± 1.5	3.8 ± 1.8
Micro distortion	4.1 ± 1.2[b]	4.3 ± 1.0[b]	3.0 ± 0.9[c]
Fibrousness	6.2 ± 1.6	5.6 ± 1.4	5.1 ± 1.1
Partial compression			
Springiness	10.5 ± 1.3	10.2 ± 2.5	9.5 ± 2.0
First bite			
Hardness	7.8 ± 0.9	8.2 ± 1.7	6.6 ± 2.3
Cohesiveness	8.8 ± 1.6	9.2 ± 1.2	9.3 ± 1.1
Moisture release	6.7 ± 1.9	6.6 ± 1.9	5.6 ± 1.8
Uniformity	10.8 ± 0.9	10.8 ± 0.9	11.7 ± 1.7
Mastication			
Juiciness	7.5 ± 1.5	7.5 ± 2.0	7.2 ± 1.8
Size of chewed particles	9.4 ± 1.7	9.6 ± 0.8	10.1 ± 1.7
Cohesiveness of mass	9.2 ± 1.9	9.1 ± 1.3	8.9 ± 1.2
Uniformity of mass	10.8 ± 1.2[c]	10.8 ± 0.7[c]	11.8 ± 1.5[b]
Gristle	2.2 ± 1.3[b]	1.9 ± 1.0[b]	0.9 ± 0.9[c]
Webbed tissue	2.9 ± 1.3	2.8 ± 1.5	2.1 ± 1.2
Number of chews	54.7 ± 7.5	58.4 ± 8.7	54.6 ± 7.9
After swallow			
Tooth pack	3.4 ± 1.4	3.2 ± 1.2	2.3 ± 0.5
Mouth coating	5.9 ± 1.1	6.0 ± 1.3	5.0 ± 1.5

[a]Definitions for the various characteristics are given in Appendix Table 3.

[b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 44. Frequency of fragmentation categories in restructured beef steaks as affected by blade tenderization.

	Number of passes through blade tenderizer		
Fragmentation category[a]	0	2	12
Complete shearing	25.0	37.9	29.0
Incomplete shearing--threads	40.6	41.4	19.4
Incomplete shearing--crust	18.8	17.2	22.6
Complete crumbly separation	0.0	0.0	0.0
Incomplete crumbly separation--threads	6.2	0.0	0.0
Incomplete crumbly separation--crust	0.0	0.0	0.0
Compacts along shear line	6.2	0.0	12.9
Chunky and complete separation	3.1	0.0	3.2
Incomplete chunky separation--threads	0.0	3.4	3.2
Incomplete chunky separation--crust	0.0	0.0	0.0
Layered separation	0.0	0.0	6.4
Other	0.0	0.0	3.2

[a]Values are percentage frequencies of sample evaluations within passes of the blade tenderizer that were classified into the fragmentation categories.

Table 45. Effects of blade tenderization on cooking properties and Instron values for restructured steaks.

Characteristic	Number of passes through blade tenderizer		
	0	2	12
Cooking properties			
Degree of doneness score	3.6[b]	3.2[b]	4.8[a]
Cooking time, min	29.0	27.1	27.2
Cooking loss, %	28.2 ± 2.9[a]	24.7 ± 2.1[b]	21.6 ± 3.0[b]
Change in steak thickness from raw to cooked, sides, %	-10.9 ± 5.8[a]	9.0 ± 6.1[b]	4.8 ± 9.5[b]
Change in steak thickness from raw to cooked, center %	-11.6 ± 5.5[a]	13.5 ± 11.1[b]	6.3 ± 1.7[b]
Change in steak diameter from raw to cooked, %	-15.7 ± 2.8	-18.2 ± 2.9	-17.0 ± 3.2
Instron			
Maximum shear force, kg	15.4 ± 1.3[a]	14.1 ± 1.3[ab]	13.2 ± 1.1[b]
Newtons/cm^2	22.2 ± 4.3[a]	14.6 ± 1.5[b]	14.5 ± 0.9[b]

[a,b]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Conclusions

With USDA Choice Yield Grade 2 and 3 chuck meat that has heavy connective tissue deposits removed, blade tenderization does not greatly affect textural properties as discerned by a panel. However, shear values were reduced with blade tenderization, especially when steak thickness was considered. Blade tenderization (both 2 and 12X) reduced cooking losses, but increased steak swelling. It does not appear that with USDA Choice chucks that blade tenderization offers enough advantages to be economically feasible to processors.

EFFECTS OF FLAKE SIZE ON TEXTURE PROFILE PANEL, INSTRON AND COOKING PROPERTIES OF RESTRUCTURED PORK STEAKS

Introduction

At this point in the project, restructured beef steaks continued to show wide variability in textural properties and efforts through processing and cooking did little to reduce the variability. It was decided to evaluate the effects of flake size (Comitrol head size) with pork, since restructured pork cuts had been developed and adopted by DOD as a menu item with a minimum of problems. It was felt that perhaps a reduced level of connective tissue in pork compared to beef might reduce the variability enough to permit isolation and refinement of textural measuring procedures that might be used with beef. Chesney et al. (1978) found restructured pork chops made from large flake particles to be less desirable in taste panel cohesion, juiciness, tenderness, and overall acceptability than chops made from small flake particles.

Materials and Methods

Restructured pork steaks were made in the same manner as previous restructured beef steaks, except that salt was deleted. Variations in particle size were used (1610, 1620, old 750, new 750, 510, 060). Steaks were cooked on preheated Farberware grills. Steaks were cooked on one side for 15 min, turned, thermocouples inserted and then turned frequently for even browning. When juices coming from the steaks were clear and the internal temperature was at least 75° C, the steaks were removed from the grills.

Results and Discussion

Both macro and micro distortion was rated as being more extensive in the 1610, 1620 and 510 steaks (Table 46). Fibrousness decreased as particle sizes decreased. First bite hardness were highest in 1610 steaks and lowest in the 060 steaks. Uniformity of first bite tended to increase with a decrease in particle size.

Decreases in particle size generally produced less cohesiveness, more uniformity of mass, less gristle and webbed tissue and fewer number of chews during mastication procedures. Compared to beef, the use of pork reduced some variability in texture panel results, but mainly with the 060 head size product. With the exception of uniformity, pork usage reduced the differences between head sizes for first bite characteristics. Replacing beef with pork resulted in less connective tissue in the resultant restructured steaks; although not as much as expected. Perhaps removing or reducing connective tissue minimizes variability in textural properties other than those directly associated with connective tissue.

Restructured pork steaks made with the 1610 head were characterized as having less complete shearing and more chunky (with or without complete separation) breakdown compared to the other head sizes (Table 47). Similar differences were found with beef (Table 21). Layered separation appeared higher in steaks processed with small size particles.

Cooking losses were higher for the pork steaks compared to beef steaks due largely to the longer cooking times (Table 48). Physical measurements of diameter and thickness revealed a shrinkage in diameter and a swelling in thickness similar to that found for beef steaks. The major differences in shear force were in the lower values obtained for product made with the 060 head compared to the other heads. With beef, differences between 1610 and 750 head sizes in shear force have been much larger.

Table 46. Effects of Comitrol head sizes on texture profile panel scores for restructured pork steaks.

Characteristic[a]	1610	1620	Old 750	New 750	510	060
	Comitrol head size					
Visual						
Macro distortion	5.0 ± 1.3^{b}	5.4 ± 2.6^{b}	3.7 ± 1.7^{c}	2.6 ± 0.6^{d}	6.1 ± 0.5^{b}	3.8 ± 2.1^{cd}
Micro distortion	5.5 ± 1.5^{b}	4.2 ± 1.0^{bc}	3.6 ± 0.6^{cd}	3.6 ± 1.4^{cd}	4.9 ± 1.3^{bc}	2.8 ± 1.4^{d}
Fibrousness	7.6 ± 2.2^{bc}	8.6 ± 0.9^{b}	6.0 ± 1.4^{c}	6.5 ± 0.6^{c}	6.4 ± 1.3^{c}	3.7 ± 1.7^{d}
Partial compression						
Springiness	8.7 ± 1.7	7.9 ± 2.8	9.7 ± 2.2	8.0 ± 2.7	8.7 ± 1.8	6.9 ± 2.7
First bite						
Hardness	9.3 ± 2.0^{b}	7.8 ± 1.5^{c}	6.7 ± 0.9^{cde}	6.1 ± 1.5^{de}	7.0 ± 1.3^{cd}	5.1 ± 0.9^{e}
Cohesiveness	9.2 ± 1.8	8.7 ± 1.9	8.4 ± 1.9	7.6 ± 1.3	8.3 ± 1.3	7.1 ± 1.4
Moisture release	5.4 ± 1.9	4.6 ± 1.7	4.9 ± 1.0	4.9 ± 1.4	4.0 ± 1.0	5.6 ± 1.4
Uniformity	6.9 ± 2.4^{e}	9.8 ± 2.9^{d}	12.1 ± 1.4^{bc}	11.7 ± 1.8^{bc}	10.9 ± 1.9^{cd}	13.1 ± 1.2^{b}
Mastication						
Juiciness	5.7 ± 1.2	6.0 ± 2.0	6.4 ± 0.8	6.1 ± 1.9	5.2 ± 1.5	6.3 ± 1.8
Size of chewed particles	9.1 ± 1.9	8.4 ± 1.2	8.8 ± 1.5	8.1 ± 1.4	8.3 ± 1.4	7.3 ± 1.4
Cohesiveness of mass	10.0 ± 1.4^{b}	9.3 ± 1.9^{bc}	9.4 ± 1.8^{bc}	7.4 ± 1.1^{cd}	6.6 ± 1.2^{d}	5.8 ± 1.7^{d}
Uniformity of mass	8.1 ± 2.0^{d}	10.7 ± 2.7^{c}	12.4 ± 1.6^{b}	12.7 ± 0.9^{b}	12.1 ± 1.3^{bc}	13.8 ± 0.7^{b}
Gristle	5.4 ± 2.1^{b}	2.7 ± 1.8^{c}	0.7 ± 1.1^{d}	1.3 ± 1.5^{d}	1.2 ± 1.5^{d}	0.1 ± 0.0^{d}
Webbed tissue	4.2 ± 1.2^{b}	2.2 ± 1.6^{c}	1.2 ± 0.6^{cd}	0.9 ± 0.9^{cd}	1.5 ± 1.2^{cd}	0.3 ± 0.3^{d}
Number of chews	62.8 ± 8.8^{b}	52.7 ± 14.0^{c}	48.0 ± 7.2^{cd}	45.7 ± 8.0^{cd}	43.5 ± 6.1^{d}	40.1 ± 8.4^{d}
After swallow						
Tooth pack	4.0 ± 1.2	3.6 ± 1.9	3.0 ± 1.3	3.0 ± 1.1	3.2 ± 1.3	2.8 ± 1.1
Mouth coating	5.6 ± 1.9	4.7 ± 1.8	4.2 ± 1.5	4.7 ± 1.4	4.2 ± 1.1	3.8 ± 1.1

[a]Definitions for the various characteristics are given in Appendix Table 3.

[b,c,d,e]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 47. Frequency of fragmentation categories in restructured pork steaks according to Comitrol head size.

	Comitrol head size					
Fragmentation category[a]	1610	1620	Old 750	New 750	510	060
Complete shearing	6.2	28.1	40.0	27.6	34.4	53.6
Incomplete shearing--threads	12.5	28.1	20.0	34.5	15.6	7.1
Incomplete shearing--crust	3.1	9.4	15.0	10.3	6.2	17.9
Complete crumbly separation	0.0	3.1	0.0	0.0	0.0	0.0
Incomplete crumbly separation--threads	0.0	0.0	0.0	3.4	3.1	3.6
Incomplete crumbly separation--crust	0.0	0.0	5.0	3.4	3.1	0.0
Compacts along shear line	9.4	9.4	5.0	13.8	9.4	3.6
Chunky and complete separation	15.6	3.1	5.0	0.0	3.1	0.0
Incomplete chunky separation--threads	28.1	12.5	10.0	3.4	3.1	0.0
Incomplete chunky separation--crust	18.8	3.1	0.0	0.0	3.1	3.6
Layered separation	3.1	3.1	0.0	3.4	18.8	10.7
Other	3.1	0.0	0.0	0.0	0.0	0.0

[a]Values are percentage frequencies of sample evaluations within Comitrol head sizes that were classified into the fragmentation categories.

Table 48. Effects of Comitrol head sizes on cooking properties and Instron values for restructured pork steaks.

Characteristic	Commitrol head size 1610	1620	Old 750	New 750	510	060
Cooking properties						
Degree of doneness score	2.2 ± 0.3^{a}	2.2 ± 0.3^{a}	2.0 ± 0.1^{b}	2.0 ± 0.0^{b}	2.1 ± 0.2^{ab}	2.2 ± 0.2^{a}
Cooking time, min	38.6 ± 2.4^{b}	35.3 ± 2.9^{c}	43.0 ± 1.6^{a}	36.3 ± 1.4^{bc}	35.0 ± 2.3^{c}	42.7 ± 0.7^{a}
Cooking loss, %	38.2 ± 3.2^{a}	34.3 ± 2.5^{c}	37.5 ± 1.7^{ab}	37.4 ± 1.8^{ab}	35.2 ± 2.0^{bc}	34.8 ± 2.3^{bc}
Change in steak thickness from raw to cooked, sides, %	-16.8 ± 3.5^{abc}	-19.8 ± 6.2^{ab}	-12.7 ± 5.7^{bc}	-17.0 ± 5.7^{abc}	-10.4 ± 10.8^{c}	-21.6 ± 3.5^{a}
Change in steak thickness from raw to cooked, center, %	-8.6 ± 7.0	-17.5 ± 5.0	-5.5 ± 8.7	-13.7 ± 7.2	-9.4 ± 13.4	-16.5 ± 4.9
Change in steak diameter from raw to cooked %	-18.9 ± 2.2^{a}	-11.4 ± 1.5^{c}	-16.4 ± 3.2^{ab}	-18.0 ± 2.2^{a}	-14.5 ± 1.7^{b}	-10.0 ± 2.1^{c}
Instron						
Maximum shear force, kg	22.5 ± 2.2^{a}	19.6 ± 1.6^{b}	13.8 ± 1.4^{c}	17.6 ± 1.7^{b}	19.0 ± 3.0^{b}	10.0 ± 1.4^{d}
Newtons/cm^2	29.5 ± 4.5^{a}	27.0 ± 2.1^{a}	16.8 ± 1.3^{c}	23.8 ± 2.1^{b}	23.4 ± 2.4^{b}	13.9 ± 1.7^{c}

[a,b,c,d]Means in the same line bearing different superscripts are significantly ($P < 0.05$) different.

Conclusions

The use of pork in place of beef to reduce variability was generally unsuccessful. Some reduction was noted in standard deviations for textural properties of steaks made with the 060 head. However, detectable connective tissue levels were about as high for these pork products as for beef. Furthermore measurable changes in thickness - diameter (distortion) were comparable to beef.

SURFACE METHODS TO REDUCE DISTORTION IN RESTRUCTURED PORK STEAKS DURING COOKING

Introduction

Distortion (concurrent swelling and shrinking) of restructured meat products during cooking has been identified (Field, 1983) as a major problem with these types of products. In the course of this project, we have certainly noted this to be a frequent, and in our opinion, severe problem that potentially can alter textural properties.

Materials and Methods

Spike penetration. A device consisting of 2.5 mm wide spikes set 1.25 cm apart was constructed. Thus, the distance from any perforation hole to another in a restructured steak was 1.25 cm. For this study, restructured pork steaks (1620 and 060 head sizes) from the previous study were used. Steaks were placed on preheated Farberware grills for 5 min, then they were removed and the sides that were in contact with the heat were "spiked." The spikes were inserted at least halfway into the steaks. The steaks were replaced on the grills and cooked another 10 min. At this time, the side of the steaks not exposed to heat was "spiked" and then this side was placed towards the heat. Steaks were then cooked approximately another 15 min until juices were clear and the internal temperature at least 76° C.

Lined indentations. For steaks receiving lined indentations, a device with a row of 2.5 mm wide prongs, set 1.0 cm apart, was used. Steaks were placed on preheated Farberware grills for 1 min and then were removed and

the side of the steaks in contact with the heat was "scraped" across the steaks in a straight line with the prong device. The indentations were 2 mm deep. The steaks were returned to the grills with the "scraped" sides closest to the heat. After 15 min, the sides not exposed to heat were "scraped" and the steaks were turned and cooked another 15 min until juices were clear and the temperature was at least 76° C.

Results and Discussion

Macro distortion was unaffected by the two surface treatments (Table 49). The major purpose in using the surface treatments was to reduce macro-type distortion. Steaks receiving the spiked penetration had greater first bite hardness and moisture release values compared to lined indentations or no surface treatments. Uniformity of first bite and the mass were affected by an interaction of surface treatments with head sizes. Steaks made with the 1620 head and receiving spiked penetration were rated as less uniform in first bite and mass compared to the other two treatments. The surface treatments had no effect on uniformity properties of steaks made with the 060 head.

A less well done degree of cooked doneness was found in steaks receiving spiked penetration compared to the other two treatments (Table 50). Lined indentations reduced the cooking times for 1620 steaks, but increased the cooking times of 060 steaks compared to control steaks.

Conclusions

Outside of a few textural changes as a result of "spiking", these two surface treatments exerted little effect on the properties of restructured pork steaks made with considerably different flake sizes. Penetration of steak surfaces during cooking as a means of allowing gasses and steam to escape (preventing swelling) proved unsuccessful.

Table 49. Effects of steak surface treatments on texture profile panel scores for restructured pork steaks.

	Surface treatment		
Characteristic[a]	None--control	Penetration with spikes	Lined indentations
Visual			
Macro distortion	3.4 ± 1.3	3.6 ± 0.8	2.8 ± 1.0
Micro distortion	3.5 ± 1.8[c]	3.6 ± 0.5[c]	5.8 ± 1.8[b]
Fibrousness	5.8 ± 1.6	6.5 ± 3.0	7.2 ± 2.4
Partial compression			
Springiness	8.0 ± 1.72	7.1 ± 1.2	6.6 ± 1.8
First bite			
Hardness	5.3 ± 1.5[c]	6.7 ± 2.0[b]	5.1 ± 1.2[c]
Cohesiveness	7.0 ± 2.0	7.3 ± 2.1	6.5 ± 1.7
Moisture release	4.5 ± 0.8[c]	5.3 ± 0.5[b]	4.5 ± 0.7[c]
Mastication			
Juiciness	4.9 ± 1.2	6.1 ± 0.9	5.8 ± 2.1
Size of chewed particles	7.2 ± 1.8	6.6 ± 1.2	6.9 ± 1.2
Cohesiveness of mass	6.9 ± 2.2	7.4 ± 2.2	6.9 ± 2.9
Gristle	1.4 ± 1.3	2.4 ± 2.1	2.1 ± 2.0
Webbed tissue	1.6 ± 1.4	1.6 ± 2.5	0.9 ± 0.9
Number of chews	41.8 ± 6.4	43.0 ± 10.0	40.1 ± 5.8
After swallow			
Tooth pack	3.7 ± 1.7	3.6 ± 1.3	3.2 ± 0.9
Mouth coating	3.6 ± 0.5	4.4 ± 1.2	3.6 ± 1.3
Significant (P < 0.05)			
Interactions			
First bite uniformity			
1620 head	10.5	6.4	10.1
060 head	13.0	13.2	13.0
Uniformity of mass			
1620 head	11.0	7.4	10.3
060 head	13.3	13.8	13.6

[a]Definitions for the various characteristics are given in Appendix Table 3.

[b,c]Means in the same row bearing different superscripts are significantly (P < 0.05) different.

Table 50. Effects of steak surface treatments on cooking properties of restructured pork steaks.

Characteristic	Surface treatment		
	None-control	Penetration with spikes	Lined indentations
Cooking properties			
Degree of doneness score	2.0 ± 0.0^{b}	2.5 ± 0.1^{a}	2.1 ± 0.4^{b}
Cooking loss, %	34.9 ± 2.0	34.3 ± 1.7	34.6 ± 1.9
Cooking time, min, interaction with head size			
1620	44.8	44.7	41.6
060	37.2	41.7	44.5

[a,b]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

CONSUMER RESPONSE TO RESTRUCTURED BEEF STEAKS PROCESSED TO HAVE VARYING LEVELS OF CONNECTIVE TISSUE

Introduction

Recently a National meeting of industry groups and scientists was held to establish research needs and priorities for beef products. Development of intermediate value products such as restructured beef steaks was classified as one of several No. 1 priorities under short term goals. A task force designed to develop the intermediate value of beef products has further identified the detrimental effects of connective tissue in restructured steaks as a research problem requiring considerable attention (Breidenstein, 1982). However, very few studies have been reported on the effects of connective tissue levels on processing, cooking and palatability factors in restructured beef products. Use of round rather than chuck muscles has been shown to result in less detectable connective tissue in restructured steaks (Booren, et al., 1981). Furthermore, the importance that consumers delegate to connective tissue in these types of products has not been established. Therefore, the purpose of this study was to determine the effects of wide ranges in connective tissue on consumers' detectability of connective tissue in restructured beef steaks and the subsequent acceptability of these products.

Materials and Methods

USDA Choice, Yield Grade 2 or 3 square-cut chucks served as the basic raw material for the restructured steaks. Four connective tissue levels of low, regular high and extra high were selected. Boneless chuck meat

intended for the low level was trimmed of all heavy deposits of connective tissue. For the high level, the boneless meat received no trimming of connective tissue and all the connective tissue removed from the low level treatment was added to these trimmings. With the regular level, just heavy layers of connective tissue were removed. The extra high level consisted to 60% boneless chucks and 40% boneless foreshank meat. There was no trimming of connective tissue in either of these two sources of raw material. The meat was tempered to -1° C and flake-cut through an Urschel comitrol 2J030750-D head. The flaked meat was mixed with 0.5% NaCl and 0.25% $Na_5P_3O_{10}$. The meat was stuffed under vacuum and 3.5 kg logs were forzen to -18° C and then tempered to -1° C. Steaks were sliced with a Bettcher cleaver to produce 170 g steaks (1.78 cm thick). Steaks were frozen to -18° C and stored at -18° C in vacuum packages for 30 days prior to consumer testing.

A total of 500 consumers (of equal representation between males and females) were selected from the Greater Washington, D.C. Metropolitan Area (GWDCMA) to participate in the consumer response studies. Only consumers between 20 and 70 years of age were selected and the number of individuals in different age categories was similar to the 1980 US Bureau of Census Report for GWDCMA. Ten groups of 50 consumers (each group balanced as to sex and complying with the GWDCMA age distribution) were used to evaluate specific comparisons of the connective tissue levels and respond to various questions concerning desirability, detectability and acceptability. The ten specific consumer tests were: (1) Consumers were given steaks of three different levels of connective tissue, told they were intact muscle steaks, and were asked to indicate acceptability and list desirable characteristics, (2) the only difference between this test

and test 1 was that consumers were told products were restructured steaks, (3) consumers were given steaks of three different levels of connective tissue, told they were intact muscle steaks, and were asked to indicate acceptability and list undesirable characteristics, (4) the only difference between this test and test 3 was that consumers were told products were restructured steaks, (5) consumers were given steaks of three different levels of connective tissue, told they were restructured steaks, were asked to indicate acceptability and compared the product given to their memory of such products in terms of gristle, (6) the only difference between this test and test 5 was that the regular connective tissue product was given three times in a row, (7) consumers were given just the high connective tissue product for acceptability and memory comparisons, told they were restructured steaks and compared extra high and low connective tissue steaks for amount of gristle, (8) same as test 7 except consumers were given extra high connective tissue steaks for memory comparison and compared high and low connective tissue steaks, (9) same as tests 7 and 8, except consumers were given low connective tissue steaks for memory comparison and compared extra high and high connective tissue steaks, and (10) consumers were given extra high, high and low connective tissue steaks in strips (thus had to cut samples) and asked for acceptability and memory comparisons. Steaks were cooked to 70° C on electric broiler units. Steaks were turned frequently to maintain even browning.

In addition to the consumer acceptance studies, a nine-member trained texture profile panel evaluated cooked steaks for 20 different textural attributes. Various Instron measurements were taken and hydroxyproline analyses were conducted to determine collagen levels.

Results and Discussion

Scores by the texture profile panel for macro distortion differed among the connective tissue levels, but followed no trends (Table 51). First bite hardness was higher for extra high steaks vs high steaks. Uniformity of first bite followed a trend of greater uniformity as connective tissue levels decreased.

Uniformity of the mass increased with decreasing levels of connective tissue in the steaks (Table 52). Extra high levels had greater number of chews, more gristle at 10 chews and more overall gristle compared to the other connective tissue levels. Webbed tissue amounts did not differ among the connective tissue levels. Actually, both gristle and webbed tissue levels were not nearly as divergent between connective levels as was expected. This point must be remembered in further discussions of this study dealing with consumer opinion.

Specific comparisons of extra high, high and low connective tissue steaks in terms of which had the most consumer detected connective tissue is given in Table 53. Consumers were usually able to find more gristle in the extra high vs high and extra high vs low steaks. However, in three out of four comparisons, consumers found higher levels of detectable connective tissue in the low compared to the high steaks. Close to being statistically significant was the sex effect for detecting connective tissue in the extra high vs high connective tissue steaks.

Consumers who eat beef more frequently (over four times/week) seemed to be better able to separate the three connective tissue levels on the basis of gristle (Table 54). This effect was significant ($P<.04$) in the comparison of high vs low steaks. Onlv 30% of the consumers that eat beef between two and four times/week found the high connective tissue steaks to

Table 51. Effects of connective tissue levels in restructured steaks on texture panel surface, partial compression and first bite evaluations.*

Characteristic	Connective tissue levels: Extra high	High	Regular	Low
Surface				
Macro distortion	5.8 + 1.4[b]	8.2 + 1.6[a]	4.6 + 1.0[c]	6.7 + 1.5[b]
Micro distortion	5.8 + 1.5	5.1 + 2.0	4.5 + 0.7	5.6 + 2.0
Fibrousness	5.3 + 3.0	6.5 + 2.3	5.6 + 1.4	6.8 + 2.2
Partial compression				
Springiness	9.9 + 2.5	8.2 + 2.5	9.6 + 2.5	9.8 + 3.3
First bite				
Hardness	8.2 + 3.5[a]	6.1 + 2.2[b]	7.4 + 2.8[ab]	7.1 + 1.7[ab]
Cohesiveness	10.2 + 3.0	7.6 + 2.5	9.3 + 2.1	9.2 + 1.6
Moisture release	6.4 + 2.3	5.4 + 2.2	6.2 + 1.9	6.3 + 1.8
Uniformity	9.1 + 3.0[b]	9.9 + 2.4[b]	12.0 + 1.3[a]	11.8 + 1.1[a]

*Definitions of texture characteristics are in Appendix Table 4.

[a,b,c]Means in same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 52. Effects of connective tissue levels in restructured steaks on texture panel masticatory and after-masticatory evaluations.*

Characteristic	Connective tissue level: Extra high	High	Regular	Low
Masticatory				
Juiciness	7.2 ± 1.4	6.3 ± 1.9	7.3 ± 2.3	7.4 ± 1.9
Size of chewed pieces	10.2 ± 2.3	8.7 ± 2.0	9.0 ± 2.0	8.5 ± 1.8
Cohesiveness of mass	8.8 ± 2.6	8.1 ± 2.2	8.6 ± 1.9	10.1 ± 2.2
Cohesiveness of mass--chew count	27.7 ± 5.1	23.4 ± 5.1	25.2 ± 5.4	23.3 ± 5.0
Uniformity of mass	8.1 ± 2.5[c]	9.5 ± 3.1[bc]	10.6 ± 2.1[ab]	11.9 ± 1.7[a]
Number of chews	63.4 ± 10.1[a]	43.4 ± 10.9[b]	52.4 ± 8.1[b]	54.7 ± 11.6[b]
Gristle--10 chews	5.5 ± 4.3[a]	2.9 ± 2.7[b]	1.0 ± 0.9[b]	1.3 ± 1.8[b]
Overall gristle	5.8 ± 4.4[a]	2.5 ± 2.1[b]	1.5 ± 1.3[b]	1.2 ± 1.5[b]
Webbed tissue--end of chewing	4.5 ± 2.3	2.8 ± 2.5	3.6 ± 2.5	2.4 ± 3.1
Overall webbed tissue	5.2 ± 2.9	4.2 ± 3.0	4.5 ± 2.9	3.7 ± 3.3
After-masticatory				
Tooth pack	3.4 ± 1.9	2.6 ± 1.6	2.1 ± 1.0	1.9 ± 1.2
Mouth coating	6.2 ± 1.4	4.4 ± 2.0	4.6 ± 2.2	4.8 ± 1.5

*Definitions of texture characteristics are in Appendix Table 4.

[abc]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 53. Effects of sex and age of consumers in detecting which samples had the most connective tissue.*

Test comparison	Sex		Age, years	
	Males	Females	< 40	40 and over
Extra-high	84.0	59.1	80.0	66.7
vs				
high	16.0	40.9	20.0	33.3
Chi-square, probability	3.6, P = .06		1.0, P = .31	
High	36.0	52.0	45.8	42.3
vs				
low	64.0	48.0	54.2	57.7
Chi-square, probability	1.3, P = .25		.06, P = .80	
Extra-high	84.0	80.8	88.0	77.8
vs				
low	16.0	19.2	12.0	22.2
Chi-square, probability	.09, P = .76		.95, P = .33	

*Values are percentage values of frequencies indicating within either sex or age which test product was thought to have the greatest amount of gristle.

Table 54. Effects of consumers level of beef consumption at home on detecting which samples had the most connective tissue.*

Test comparison	Times/week beef consumed at home: 2 or less	Over 2 to 4 inclusive	Over 4
Extra High	60.0	72.2	79.0
vs			
High	40.0	27.8	21.0
Chi-square, probability		1.2, P = .56	
High	62.5	30.0	66.7
vs			
Low	37.5	70.0	33.3
Chi-square, probability		6.0, P = .04	
Extra high	63.6	86.7	90.9
vs			
Low	36.4	13.3	9.1
Chi-square, probability		3.6, P = .16	

*Values are percentage values of frequencies indicating within times/week consumption which test product was thought have the greatest amount of gristle. Different groups made the three comparisons.

have more gristle than the low connective tissue steaks.

No significant effects were found for consumers preference for cooked degree of doneness and their ability to detect which samples had the most connective tissue (Table 55). Again, consumers were unable to detect more connective tissue in the high compared to the low connective tissue steaks.

Consumers who dislike gristle in beef were more accurate in determining which steaks had more gristle (Table 56). For comparing extra high vs high and high vs low connective tissue steaks, consumers who consider texture as the factor they like least about beef were the least accurate.

Regardless of connective tissue levels, males and females had similar frequencies of desirable characteristics when told the samples were restructured steaks (Table 57). Especially for females, there was a slight indication that they felt that low connective tissue steaks had less gristle. However, in all connective tissue levels, consumers did not feel that a low level of connective tissue was an inherent desirable characteristic. Texture and flavor were considered as the most desirable characteristics. There was indication, especially for females, that flavor desirability was higher in the extra high compared to the high and low steaks.

Desirable characteristics of these steaks when consumers were told they were intact muscle steaks are given in Table 58. Males and females did not differ in their general responses. However, females felt that leanness was more of a desirable characteristic and juiciness less of a desirable characteristic in extra high steaks compared to the other two treatments. In contrast to consumers responses when they were told the

Table 55. Effects of consumers preference for cooked degree of doneness in detecting which samples had the most connective tissue.*

Test comparison	Degree of doneness: Well done	Medium	Rare
Extra High	85.7	58.8	75.0
vs			
High	14.3	41.2	25.0
Chi-square, probability		2.9, P = .24	
High	50.0	31.2	50.0
vs			
Low	50.0	68.8	50.0
Chi-square, probability		1.6, P = .46	
Extra high	85.7	80.0	81.2
vs			
Low	14.3	20.0	18.8
Chi-square, probability		0.2, P = .89	

*Values are percentage values of frequencies indicating within either sex or age, which test product was thought to have the greatest amount of gristle. Different groups made the three comparisons.

Table 56. Effects of factors that consumers like least about beef on detecting which samples had the most connective tissue.*

	Factors consumers like least about beef			
Test comparison	Gristle	Texture	Excess fat	Other
Extra high	100.0	58.2	71.4	83.3
vs				
High	0.0	41.2	28.6	16.7
Chi-square, probability		3.8, P=.28		
High	60.0	37.5	60.0	36.4
vs				
Low	40.0	62.5	40.0	63.6
Chi-square, probability		2.2, P=.52		
Extra high	90.9	85.0	77.8	75.0
vs				
Low	9.1	15.0	22.2	25.0
Chi-square, probability		1.2, P=.74		

*Values are percentage values of frequencies indicating within factors consumers like least about beef, which product was thought to have the greatest amount of gristle. Different groups made the three comparisons.

Table 57. Effects of sex of consumer and connective tissue levels in restructured steaks on consumer's response to desirable characteristics of restructured steaks when told they were restructured steaks*.

	Connective tissue levels		
Sex, characteristic	Extra high	High	Low
Males			
Low amount of gristle	1.5	4.0	2.6
Texture, tenderness, firmness	33.8	35.1	36.4
Juiciness	10.3	12.2	13.0
Flavor, aroma	41.2	36.5	36.4
Leanness	4.4	6.8	6.5
Appearance	8.8	5.4	5.2
Females			
Low amount of gristle	1.5	5.4	6.3
Texture, tenderness, firmness	28.1	35.1	35.4
Juiciness	12.5	17.6	16.5
Flavor, aroma	45.3	32.4	31.6
Leanness	6.2	4.1	5.1
Appearance	6.2	5.4	5.1
Chi-square, probability	1.5, P = .91	0.9, P = .64	1.9, P = .85

*Values are percentage values of frequencies indicated within connective tissue levels and sex.

Table 58. Effects of sex of consumer and connective tissue levels in restructured steaks on consumer's response to desirable characteristics of restructured steaks when told they were intact muscle steaks.*

Sex, characteristic	Connective tissue levels: Extra high	High	Low
Males			
Low amount of gristle	0.0	0.0	0.0
Texture, tenderness, firmness	33.3	37.5	33.3
Juiciness	7.1	7.5	11.1
Flavor, aroma	38.1	30.0	35.2
Leanness	7.1	7.5	1.8
Appearance	14.3	17.5	18.5
Females			
Low amount of gristle	1.8	5.4	4.0
Texture, tenderness, firmness	36.8	33.9	26.7
Juiciness	7.0	17.9	14.7
Flavor, aroma	31.6	28.6	38.7
Leanness	10.5	1.8	5.3
Appearance	12.3	12.5	10.7
Chi-square, probability	1.5, P = .91	6.3, P = .28	5.4, P = .37

*Values are percentage values of frequencies indicated within connective tissue levels and sex.

products were restructured steaks (Table 57), consumers liked the appearance more, but juiciness less when they were told the products were intact muscle steaks.

When consumers were told to list undesirable characteristics of samples identified as restructured steaks, separation of the connective tissue levels on the statement "high amount of gristle" was more apparent (Table 59). Again, males and females did not differ in their responses. In addition to high levels of gristle, extra high steaks also were indicated as having more undesirable texture than the other two treatments. Appearance seemed to be more undesirable in the low connective tissue steaks.

Undesirable characteristics identified by consumers when told the samples were intact muscle steaks are given in Table 60. In this situation, none of the consumers in this test felt that the level of gristle in the low connective tissue steaks was excessive. Actually, the frequency of responses for excessive gristle is not very high in extra high connective tissue steaks. Texture, etc. was identified as an undesirable characteristic of extra high connective tissue steaks. Flavor and aroma as an undesirable characteristic seemed to be very prevalent in low connective tissue steaks. We have no reason to expect that the removal of connective tissue leads to undesirable flavors; thus it may be an increase simply because gristle is no longer a factor to identify in low connective tissue steaks. Again, appearance seems to be a problem in low connective tissue steaks. In comparing these results with those of Table 59 (told product was restructured steaks), one of the major differences is that when the product was identified as intact muscle steaks, excess fat is less of a problem than when the product is

Table 59. Effects of sex of consumer and connective tissue levels in restructured steaks on consumer's response to undesirable characteristics of restructured steaks when told they were restructured steaks.*

	Connective tissue levels		
Sex, characteristic	Extra high	High	Low
Males			
High amount of gristle	18.9	7.1	5.5
Texture, toughness, firmness	36.5	26.2	30.5
Dryness	6.8	4.8	8.3
Flavor, aroma	20.3	38.1	36.1
Excess fat	10.8	11.9	2.8
Appearance	6.8	11.9	16.7
Females			
High amount of gristle	22.5	19.2	12.9
Texture, toughness, firmness	30.0	23.1	19.4
Dryness	3.8	1.9	3.2
Flavor, aroma	22.5	32.7	25.8
Excess fat	11.2	13.5	22.6
Appearance	10.0	9.6	16.1
Chi-square, probability	1.9, P = .85	3.4, P = .62	8.6, P = .13

*Values are percentage values of frequencies indicated within connective tissue levels and sex.

Table 60. Effects of sex of consumer and connective tissue levels in restructured steaks on consumer's response to undesirable characteristics of restructured steaks when told they were intact muscle steaks*.

	Connective tissue levels		
Sex, characteristic	Extra high	High	Low
Males			
High amount of gristle	10.7	11.6	0.0
Texture, toughness, firmness	50.0	39.5	38.7
Dryness	7.1	4.6	9.7
Flavor, aroma	21.4	37.2	35.5
Excess fat	5.4	4.6	3.2
Appearance	5.4	2.3	12.9
Females			
High amount of gristle	19.7	16.3	0.0
Texture, toughness, firmness	39.3	20.9	31.6
Dryness	6.6	7.0	0.0
Flavor, aroma	18.0	37.2	42.1
Excess fat	8.2	4.6	10.5
Appearance	8.2	14.0	15.8
Chi-square, probability	3.1, P = .68	6.6, P = .25	3.3, P = .52

*Values are percentage values of frequencies indicated within connective tissue levels and sex.

identified as being restructured steak.

Acceptability values for extra high, high and low connective tissue steaks (identified as restructured steaks) are presented in Table 61. One of the major findings is that very few males in Test I found any of the connective tissue levels very acceptable. In contrast to females, this was significant ($P<.03$) for extra high steaks. In both tests, females found extra high steaks to be "very acceptable" more often than low connective tissue steaks. In fact, as connective tissue levels decreased, regardless of test or sex, the frequency of scores assigned as not acceptable increased. Again, these results may reflect the problem associated with flavor (Table 60).

Acceptability data according to sex for samples identified as intact muscle steaks are presented in Table 62. Males had very similar responses in both tests. Females found in Test II more of the high steaks to be very acceptable and less of the low steaks to be very acceptable compared to Test I. In this situation, where consumers were told the products were intact muscle steaks, the connective tissue levels were either not important or detectable since the percentage response for samples being "not acceptable" in low connective tissue steaks was anywhere from 3 to 20 times higher than in extra high connective tissue steaks. In terms of separating the three treatments for acceptability, the consumers illustrated more differentiation when they were told the samples were intact muscle steaks rather than restructured steaks (Table 61).

The influence of age of consumers on identification of desirable characteristics in restructured steaks is presented in Table 63. In this particular test, age did not seem to influence the results with the

Table 61. Effect of sex and connective tissue levels in restructured steaks on consumers acceptability of restructured steaks when told they were restructured steaks.*

			Connective tissue levels		
Test	Sex	Acceptability	Extra high	High	Low
I	Males	Very acceptable	4.0	0.0	8.0
		Just acceptable	84.0	76.0	56.0
		Not acceptable	12.0	24.0	36.0
I	Females	Very acceptable	32.0	16.7	8.0
		Just acceptable	56.0	62.5	56.0
		Not acceptable	12.0	20.8	36.0
	Chi-square, probability		6.8, P=.03	4.5, P=.10	0.0, P=.10
II	Males	Very acceptable	21.7	25.0	20.8
		Just acceptable	65.2	62.5	58.3
		Not accetpable	13.0	12.5	20.8
II	Females	Very acceptable	53.8	30.8	26.9
		Just acceptable	42.3	46.2	42.3
		Not acceptable	3.8	23.1	30.8
	Chi-square, probability		5.7, P=.06	1.5, P=.46	1.3, P=.52

*Values are percentage values of frequencies indicated within sex and connective tissue levels. Test I and II refer to two different groups of consumers.

Table 62. Effects of sex, and connective tissue levels in restructured steaks on consumers acceptability of restructured steaks when told they were intact muscle steaks.*

			Connective tissue levels		
Test	Sex	Acceptability	Extra high	High	Low
I	Males	Very acceptable	18.2	18.2	4.6
		Just acceptable	68.2	59.1	45.4
		Not acceptable	13.6	22.7	50.0
I	Females	Very acceptable	44.4	22.2	18.5
		Just acceptable	51.8	66.7	40.7
		Not acceptable	3.7	11.1	40.7
	Chi-square, probability		4.6, P=.10	1.2, P=.55	2.2, P=.33
II	Males	Very acceptable	19.2	19.2	7.7
		Just acceptable	79.9	69.2	53.8
		Not accetpable	3.8	11.5	38.5
II	Females	Very acceptable	40.0	40.0	8.0
		Just acceptable	60.0	52.0	72.0
		Not acceptable	0.0	8.0	20.0
	Chi-square, probability		3.4, P=.18	2.6, P=.26	2.1, P=.34

*Values are percentage values of frequencies indicated within sex and connective tissue levels. Test I and II refer to two different groups of consumers.

able 63. Effects of age and connective tissue levels in restructured steaks on consumers' response to desirable characteristics of restructured steaks when told they were restructured steaks.*

		Connective tissue levels		
Age--Yrs	Characteristic	Extra high	High	Low
< 40	Low amount of gristle	0.0	3.1	5.3
	Texture, tenderness, firmness	34.0	43.8	43.9
	Juiciness	10.6	14.1	14.0
	Flavor, aroma	46.8	32.8	33.3
	Leanness	4.3	4.7	1.8
	Appearance	4.3	1.6	1.8
0 and over	Low amount of gristle	2.4	6.0	4.0
	Texture, tenderness, firmness	29.4	28.6	31.3
	Juiciness	11.8	15.5	15.2
	Flavor, aroma	41.2	35.7	34.3
	Leanness	5.9	6.0	8.1
	Appearance	9.4	8.3	7.1
	Chi-square, probability	2.8, P=.73	6.3, P=.28	6.2, P=.28

Values are percentage values of frequencies indicated within age and connective tissue level.

exception that consumers <40 of age apparently liked the texture, etc. more than consumers 40 and older in age. Desirability frequencies did not vary greatly among the connective tissue levels.

Age effects on categorizing desirable characteristics in restructured steaks identified as intact muscle steaks are given in Table 64. The biggest difference in the categorizing of desirable characteristics between sexes (P<.04 for extra high steaks) was the reduced incidence of "appearance" being a desirable feature of these steaks to consumers under 40 years of age. For the extra high connective tissue steaks younger consumers had a higher frequency of flavor being desirable than older consumers. There did not seem to be any major differences in the frequency patterns between the three treatments. Compared to data on age effects on desirability listings (Table 63) when identified as restructured steaks, consumers indicated when told these products were intact muscle steaks that appearance was more of a desirable characteristic and juiciness (older consumers) less of a desirable characteristic.

Undesirable characteristics of samples identified as restructured steaks according to age of consumer are given in Table 65. Responses according to connective tissue levels indicate gristle and toughness were less of a problem in low vs high connective tissue steaks. For both age groups, appearance and flavor appeared to be less of a problem in extra high steaks compared to restructured steaks made to have high and low levels of connective tissue.

When samples were identified as being intact muscle steaks, both age groups felt that gristle was not an undesirable characteristic of low connective tissue steaks (Table 66). However, flavor and appearance were more undesirable in low vs high and extra high connective tissue steaks.

Table 64. Effects of age and connective tissue levels in restructured steaks on consumers' response to desirable characteristics of restructured steaks when told they were intact muscle steaks.*

		Connective tissue levels		
Age--Yrs	Characteristic	Extra high	High	Low
< 40	Low amount of gristle	2.6	4.0	5.4
	Texture, tenderness, firmness	35.9	36.0	29.1
	Juiciness	7.7	20.0	14.6
	Flavor, aroma	41.0	26.0	38.2
	Leanness	12.8	6.0	3.6
	Appearance	0.0	8.0	9.1
40 and over	Low amount of gristle	0.0	2.2	0.0
	Texture, tenderness, firmness	35.0	34.8	29.7
	Juiciness	6.7	6.5	12.2
	Flavor, aroma	30.0	32.6	36.5
	Leanness	6.7	2.2	4.0
	Appearance	21.7	21.7	17.6
	Chi-square, probability	11.8, P=.04	7.8, P=.16	5.8, P=.32

*Values are percentage values of frequencies indicated with ages and connective tissue levels. Same group evaluated all connective tissue levels.

Table 65. Effects of age and connective tissue levels in restructured steaks on consumers' response to undesirable characteristics of restructured steaks when told they were restructured steaks.*

Age--Yrs	Characteristic	Connective tissue levels: Extra high	High	Low
< 40	High amount of gristle	19.3	11.4	14.3
	Texture, tenderness, firmness	27.7	27.3	20.0
	Dryness	3.6	2.3	2.9
	Flavor, aroma	24.1	29.6	31.4
	Excess fat	13.2	15.9	14.3
	Appearance	12.0	13.6	17.1
40 and over	High amount of gristle	22.5	16.0	3.1
	Texture, tenderness, firmness	39.4	22.0	31.2
	Dryness	7.0	4.0	9.4
	Flavor, aroma	18.3	40.0	31.2
	Excess fat	8.4	10.0	9.4
	Appearance	4.2	8.0	15.6
	Chi-square, probability	6.8, P=.23	2.9, P=.71	4.7, P=.45

*Values are percentage values of frequencies indicated within age and connective tissue levels.

Table 66. Effects of age and connective tissue levels in restructured steaks on consumers' response to undesirable characteristics of restructured steaks when told they were intact muscle steaks.*

		Connective tissue levels		
Age--Yrs	Characteristic	Extra high	High	Low
< 40	High amount of gristle	17.0	12.2	0.0
	Texture, tenderness, firmness	45.3	29.3	36.0
	Dryness	5.7	7.3	8.0
	Flavor, aroma	13.2	36.6	32.0
	Excess fat	11.3	7.3	4.0
	Appearance	7.6	7.3	20.0
40 and over	High amount of gristle	14.1	15.6	0.0
	Texture, tenderness, firmness	43.8	31.1	36.0
	Dryness	7.8	4.4	4.0
	Flavor, aroma	25.0	37.8	44.0
	Excess fat	3.1	2.2	8.0
	Appearance	6.2	8.9	8.0
	Chi-square, probability	5.3, P=.38	1.8, P=.88	2.43, P=.66

*Values are percentage values of frequencies indicated within age and connective tissue levels.

Age differences were not significant in terms of the responses to undesirability. Again, as in previous tables, consumers appear to be able to separate the three treatments when they consider them as intact muscle steaks rather than restructured steaks.

Comparisons of consumers perception of gristle in these products to their recollection of gristle in products they have previously consumed are given in Table 67. In all demographic categories, with just three exceptions, consumers thought the amount of gristle in these steaks made to have extra high connective tissue was either more than beef previously consumed or generally excessive. Females tended to be more critical of this product, if this was the only level of connective tissue they evaluated (Test II vs Test I), while the opposite was true of males. Likewise, consumers less than 40 years of age in Test I found this product more similar of beef previously eaten compared to consumers over 40 years of age in Test II.

In general, approximately 1/3 of the consumers evaluating restructured steaks made to have a high level of connective tissue (Table 68) found the gristle levels less than beef they had previously consumed. This was an increase for this category in this product compared to the extra high connective steaks in the previous table. Males differed dramatically from females in Test I where many more males than females felt this product had less gristle than beef previously consumed. Compared to consumers <40 years of age, older consumers (40 and above) felt this product had more gristle than product they had consumed in the past.

Generally, in most demographic categories, consumers felt the amount of gristle in the low connective tissue steaks was either the same or

Table 67. Effects of sex and age on evaluations for connective tissue of restructured steaks made to have an extra high level of connective tissue--cubes*.

		Compared to beef you have previously consumed, was the amount of gristle..			For beef in this form was the amount of gristle..		
Test	Sex or age, years	More	The same	Less	Excessive	About right	Not enough
I	Males	52.2	26.1	21.7	69.6	21.7	8.7
I	Females	54.6	27.3	18.2	54.6	45.4	0.0
	Chi-square, probability		0.09, P=.96			4.2, P=.12	
II	Males	56.5	17.4	26.1	48.0	52.0	0.0
II	Females	62.5	25.0	12.5	56.0	44.0	0.0
	Chi-square, probability		1.5, P=.47			0.3, P=.57	
I	< 40	40.0	35.0	25.0	60.0	40.0	0.0
I	40 and over	64.0	20.0	16.0	64.0	28.0	8.0
	Chi-square, probability		2.6, P=.27			2.1, P=.35	
II	< 40	66.7	14.3	19.0	58.3	41.7	0.0
II	40 and over	53.8	26.9	19.2	46.2	53.8	0.0
	Chi-square, probability		1.2, P=.55			0.7, P=.39	

*Values are percentage values of frequencies within sex or age, indicating the amount of gristle. Test I and II refer to two different groups of consumers. Consumers served samples as cubes. Test I consumers eventually exposed to restructured steaks of three different levels of connective tissue. Test II consumers only received restructured steaks of one level of connective tissue.

Table 68. Effects of sex and age on evaluations for connective tissue of restructured steaks made to have a high level of connective tissue-cubes.*

		Compared to beef you have previously consumed, was the amount of gristle..			For beef in this form was the amount of gristle..		
Test	Sex or age, years	More	The same	Less	Excessive	About right	Not enough
I	Males	34.8	8.7	56.5	43.5	47.8	8.7
I	Females	31.8	50.0	18.2	31.8	63.6	4.6
	Chi-square, probability		11.0, P=.004			1.2, P=.55	
II	Males	56.0	24.0	20.0	44.0	52.0	4.0
II	Females	41.2	25.0	33.3	34.6	61.5	3.8
	Chi-square, probability		1.3, P=.51			0.5, P=.78	
I	< 40	30.0	25.0	45.0	35.0	60.0	5.0
I	40 and over	36.0	32.0	32.0	40.0	52.0	8.0
	Chi-square, probability		0.8, P=.67			0.4, P=.84	
II	< 40	40.0	32.0	28.0	32.0	60.0	8.0
II	40 and over	56.0	20.0	24.0	44.4	55.6	0.0
	Chi-square, probability		1.4, P=.49			2.7, P=.26	

*Values are percentage values of frequencies within sex or age, indicating the amount of gristle. Test I and II refer to two different groups of consumers. Consumers served samples as cubes. Test I consumers eventually exposed to restructured steaks of three different levels of connective tissue. T s+ II consumers only received restructured steaks of one level of connective tissue.

about right (Table 69). The big change in response to this product compared to the high connective tissue steaks was in the category of "more" than previously consumed. Actually the number of consumers that categorized the "high and "low" steaks as less in gristle than what their memory indicated was very similar. While Test I and II were structured somewhat differently (in both tests same amount of all products served, but a given person in Test II only received one level of connective tissue) the basic results were about the same. Male consumers and consumers <40 years of age displayed a lower frequency of stating that the samples had more connective tissue compared to previously consumed beef than was the case for female and 40 and over consumers.

Data presented in Table 70 illustrates essentially how well a group of consumers repeated themselves since all three tests involved the same consumers and in all tests just one product (regular connective tissue level) was served. Females tended to classify the product in Test II as being more similar in amount of gristle and about right in volume as determined in memory comparisons in contrast to their evaluations in Test I and III. As males went through the three tests, they classified more of their responses concerning the amount of gristle as "about right" and less of their responses as "excessive." In terms of age, consumers over 40 varied somewhat in their response to memory comparisons for amount of gristle (less in Test II vs I and III). Consumers <40 years of age were fairly consistent in their responses.

Effects of sex and age on restructured steak gristle amounts (when samples served in a form requiring consumers to cut samples) are given in Table 71. Responses by males and females and young and older consumers were virtually identical for steaks with extra high levels of connective

Table 69. Effects of sex and age on evaluations for connective tissue of restructured steaks made to have a low level of connective tissue--cubes*.

		Compared to beef you have previously consumed, was the amount of gristle..			For beef in this form was the amount of gristle..		
Test	Sex or age, years	More	The same	Less	Excessive	About right	Not enough
I	Males	13.0	52.2	34.8	17.4	78.3	2.2
I	Females	18.2	45.4	36.4	13.6	86.4	0.0
	Chi-square, probability		0.3, P=.96			1.1, P=.56	
II	Males	8.0	64.0	28.0	12.0	84.0	4.0
II	Females	18.2	40.9	40.9	9.1	90.9	0.0
	Chi-square, probability		2.7, P=.26			1.0, P=.60	
I	< 40	5.0	55.0	40.0	10.0	90.0	0.0
I	40 and over	24.0	44.0	32.0	20.0	76.0	4.0
	Chi-square, probability		3.0, P=.21			1.8, P=.41	
II	< 40	10.0	55.0	35.0	10.0	85.0	5.0
II	40 and over	14.8	51.8	33.3	11.1	88.9	0.0
	Chi-square, probability		0.2, P=.89			1.4, P=.50	

*Values are percentage values of frequencies within sex or age, indicating the amount of gristle. Test I and II refer to two different groups of consumers. Consumers served samples as cubes. Test I consumers eventually exposed to restructured steaks of three different levels of connective tissue. Test II consumers only received restructured steaks of one level of connective tissue.

able 70. Effects of sex and age on repeated evaluations for connective tissue of restructured steaks made to have the same level of connective tissue.*

		Compared to beef you have previously consumed, was the amount of gristle..			For beef in this form was the amount of gristle..		
est	Sex or age, years	More	The same	Less	Excessive	About right	Not enough
I	Males	36.4	31.8	31.8	36.4	63.6	0.0
I	Females	23.1	46.2	30.8	29.6	70.4	0.0
	Chi-square, probability		1.3, P=.51			.25, P=.61	
II	Males	31.8	40.9	27.3	27.3	68.2	4.6
II	Females	11.5	53.8	34.6	18.5	77.8	3.7
	Chi-square, probability		2.9, P=.23			.58, P=.75	
II	Males	22.7	45.4	31.8	18.2	81.8	0.0
II	Females	46.2	38.5	15.4	33.3	63.0	3.7
	Chi-square, probability		3.4, P=.18			2.5, P=.29	
I	< 40	35.0	40.0	25.0	33.3	66.7	0.0
I	40 and over	25.0	39.3	35.7	32.1	67.9	0.0
	Chi-square, probability		0.8, P=.66			.01, P=.93	
II	< 40	35.0	40.0	25.0	38.1	57.1	4.8
II	40 and over	10.7	53.6	35.7	10.7	85.7	3.6
	Chi-square, probability		4.2, P=.12			5.4, P=.06	
III	< 40	35.0	50.0	15.0	33.3	66.7	0.0
III	40 and over	35.7	35.7	28.6	21.4	75.0	3.6
	Chi-square, probability		1.5, P=.47			1.5, P=.47	

*Values are percentage values of frequencies indicating within sex or age, the amount of gristle. The same product (regular connective tissue level) was served in all three taste tests (I, II, III).

Table 71. Effects of sex and age on evaluations for connective tissue of restructured steaks made to have various levels of connective tissue--strips*.

		Compared to beef you have previously consumed, was the amount of gristle..			For beef in this form was the amount of gristle..		
Level of connective tissue	Sex or age, years	More	The same	Less	Excessive	About right	Not enough
Extra high	Males	54.5	31.8	13.6	63.6	36.4	0.0
Extra high	Females	54.2	33.3	12.5	64.0	36.0	0.0
	Chi-square, probability		0.02, P=.99			0.001, P=.98	
High	Males	31.8	31.8	36.4	23.8	66.7	9.5
High	Females	20.0	28.0	52.0	12.0	84.0	4.0
	Chi-square, probability		1.3, P=.51			1.9, P=.39	
Low	Males	27.3	45.4	27.3	27.3	68.2	4.6
Low	Females	20.0	28.0	52.0	12.0	88.0	0.0
	Chi-square, probability		3.0, P=.22			3.1, P=.21	
Extra high	< 40	55.0	30.0	15.0	65.0	35.0	0.0
Extra high	40 and over	53.8	34.6	11.5	63.0	37.0	0.0
	Chi-square, probability		0.2, P=.91			.02, P=.89	
High	< 40	30.0	20.0	50.0	20.0	65.0	15.0
High	40 and over	22.2	37.0	40.7	15.4	84.6	0.0
	Chi-square, probability		1.6, P=.45			4.6, P=.09	
Low	< 40	35.0	35.0	30.0	35.0	65.0	0.0
Low	40 and over	14.8	37.0	48.2	7.4	88.9	3.7
	Chi-squre, probability		2.9, P=.23			6.1, P=.05	

*Values are percentage values of frequencies within sex or age, indicating the amount of gristle. The same group of consumers were served all three products. Products served as strips, and thus consumers had to use knifes and forks to cut off their samples.

tissue. For low connective tissue steaks, some differences in response due to sex and age were noted. Only 7.4% of the consumers 40 years and older felt the amount of gristle in low connective tissue steaks was excessive, while 35.0% of the <40 year-old consumers thought it was excessive. Over half of the consumers in any demographic category thought the extra high connective tissue steaks to be higher in gristle than beef previously consumed. Over 60% of all consumers felt the gristle level to be excessive in the extra high connective tissue steaks, while the range for consumer responses to the low connective tissue steaks being excessive in gristle only ranged from 7.4 to 35.0. Compared to data where consumers were served high connective tissue steaks as cubes (Table 68), consumers given samples as strips and thus requiring cutting, found gristle to be more excessive. Perhaps cutting samples prior to placing them in the mouth gives consumers a visual and physical means of detecting gristle as well as a masticatory method, and thus is more accurate.

Data pertaining to the full 9-category acceptability system as given to consumers is presented in Table 72. Regardless of the connective tissue levels, very few consumers would consume these products often or at every opportunity. As connective tissue levels decreased, there was a greater number of responses indicating "would eat product frequently" and a general decrease in responses in the categories of "don't like product, but would eat it on occasion" and "would eat product only if no other food choice." In contrast to what was expected before the conduction of the consumer tests, these results do not portray the differences in response that were anticipated.

In order to obtain sufficient classifications for statistical analyses, the top three acceptability categories in Table 72 were grouped into a "very acceptable" group. The middle three categories were

Table 72. Expanded acceptability of restructured steaks varying in connective tissue level.*

	Connective tissue level			
Acceptability	Extra high	High	Regular	Low
Would eat product at every opportunity	2.0	0.0	6.1	0.0
Would eat product often	0.0	2.0	2.0	0.0
Would eat product frequently	6.0	9.8	14.3	14.9
Like product and would eat it now and then	32.0	33.3	28.6	40.4
Would eat product if available, but wouldn't go out of way to do so	28.0	27.4	24.5	23.4
Don't like product, but would eat it on occasion	10.0	7.8	6.1	8.5
Would hardly ever eat product	14.0	7.8	10.2	8.5
Would eat product only if no other food choice	8.0	9.8	6.1	4.3
Would eat product only if forced to	0.0	2.0	2.0	0.0

*Values are percentage values of frequencies indicating within connective tissue levels, the level of acceptability. Different groups evaluated each of the four products. Each group was not subjected to other products before determining the degree of acceptability of the particular product tested.

regrouped into "just acceptable" and the bottom three categories were reclassified as "not acceptable." The effects of age on acceptability values when consumers were told samples were restructured steaks are given in Table 73. There were no differences due to consumer's age for acceptability responses, but in Test I for high connective tissue steaks the differences were significant at $P<.08$. Test II consumers, as a rule, classified more of the samples as "very acceptable", regardless of connective tissue. Correspondingly, they had fewer of their scores in the "not acceptable" bracket compared to Test I consumers. Consumers less than 40 years of age seemed to separate the three connective tissue levels one from another better than consumers older than 40.

Telling consumers that the product was intact steak resulted in both age groups being able to better separate the connective tissue levels on the basis of acceptability (Table 74) than when told samples were restructured steak. Again, there appears to be more responses in the "very acceptable" category and fewer responses in the "not acceptable" category for extra high connective tissue steaks vs the low connective tissue steaks. This implies that: (1) either the connective tissue differences are not large enough for them to become a factor influencing acceptability, or (2) factors such as adverse flavor in low connective tissue steaks are playing a greater role in determining acceptability than gristle. In Test I, a higher percent of the younger consumers found the extra high connective tissue steaks "very acceptable" compared to older (40 and over) consumers ($P<.07$). In Test II, a higher percent of the younger consumers responses were for "just acceptable" (and a lower response in "not acceptable") with low connective tissue steaks in contrast to older consumers ($P<.03$).

Table 73. Effects of age and connective tissue levels in restructured steaks on consumers acceptability when told they were restructured steaks.*

Test	Age, years	Acceptability	Connective tissue levels		
			Extra high	High	Low
I	< 40	Very acceptable	17.4	0.0	4.4
		Just acceptable	73.9	82.6	56.5
		Not acceptable	8.7	17.4	39.1
I	40 and over	Very acceptable	18.5	15.4	11.1
		Just acceptable	66.7	57.7	55.6
		Not acceptable	14.8	26.9	33.3
	Chi-square, probability		0.5, P=.78	5.1, P=.08	0.8, P=.66
II	< 40	Very acceptable	47.8	25.0	25.0
		Just acceptable	47.8	62.5	58.3
		Not acceptable	4.4	12.5	16.7
II	40 and over	Very acceptable	30.8	30.8	23.1
		Just acceptable	57.7	46.2	42.3
		Not acceptable	11.5	23.1	34.6
	Chi-square, probability		1.9, P=.38	1.5, P=.46	2.2, P=.33

*Values are percentage values of frequencies indicated within age and connective tissue levels. Test I and II refer to two different groups of consumers.

Table 74. Effects of age and connective tissue levels in restructured steaks on consumers acceptability when told they were intact muscle steaks.*

Test	Age, years	Acceptability	Connective tissue levels: Extra high	High	Low
I	< 40	Very acceptable	45.4	27.3	22.7
		Just acceptable	54.6	54.6	40.9
		Not acceptable	0.0	18.2	36.4
I	40 and over	Very acceptable	22.2	14.8	3.7
		Just acceptable	63.0	70.4	44.4
		Not acceptable	14.8	14.8	51.8
	Chi-square, probability		5.4, P=.07	1.5, P=.48	4.3, P=.11
II	< 40	Very acceptable	26.1	26.1	4.4
		Just acceptable	69.6	69.6	82.6
		Not acceptable	4.4	4.4	13.0
II	40 and over	Very acceptable	32.1	32.1	10.7
		Just acceptable	67.9	53.6	46.4
		Not acceptable	0.0	14.3	42.9
	Chi-square, probability		1.4, P=.50	2.0, P=.38	7.1, P=.03

*Values are percentage values of frequencies indicated within age and connective tissue levels. Test I and II refer to two different groups of consumers.

The effects of consumers age and sex on acceptability when samples were served as strips are provided in Table 75. Differences between males and females were nonsignificant. The biggest differences in acceptability patterns occurred between extra high and high connective tissue steaks rather than between high and low connective tissue steaks. It doesn't appear that serving the samples as strips (requiring cutting by consumers) greatly affected acceptability.

Whether consumers were originally asked to think of the products in a positive (desirable characteristics) or negative (undesirable characteristics) manner can be evaluated in terms of acceptability in Table 76. When consumers were informed that the samples were restructured steaks, consumers actually found the steaks to be more acceptable when they had to identify undesirable characteristics rather than desirable characteristics regardless of connective tissue levels.

The effects of consumer's level of beef consumption at home on acceptability ratings of the various connective tissue levels in steaks, is given is Table 77. While differences were noted in the classification of acceptability of the three products according to times/week of beef consumption, there were no consistent trends.

Background information provided by the consumers was used to categorize the acceptability values (Table 78). Consumers who liked gristle the least in beef had the highest frequency of extra high connective tissue steaks in the "very acceptable" category and had none of the low connective tissue steaks in the "very acceptable" category. This again points out that the levels of connective tissue in these products, if detectable in a precise manner by consumers, are not very important in influencing acceptability.

Table 75. Effects of sex, age and connective tissue levels in restructured steaks on consumers acceptability of restructured steaks served in strips.*

		Connective tissue levels		
Sex, Age (Yrs)	Acceptability	Extra high	High	Low
Males	Very acceptable	22.7	9.1	9.1
	Just acceptable	68.2	72.7	72.7
	Not acceptable	9.1	18.2	18.2
Females	Very acceptable	40.0	24.0	12.0
	Just acceptable	56.0	72.0	64.0
	Not acceptable	4.0	4.0	24.0
Chi-square, probability		1.8, P=.40	3.7, P=.15	.41, P=.81
< 40	Very acceptable	30.0	25.0	20.0
	Just acceptable	70.0	65.0	70.0
	Not accetpable	0.0	10.0	10.0
40 and over	Very acceptable	33.3	11.1	3.7
	Just acceptable	55.6	77.8	66.7
	Not acceptable	11.1	11.1	29.6
Chi-square, probability		2.6, P=.26	1.6, P=.46	5.0, P=.08

*Values are percentage values of frequencies indicated within sex and connective tissue levels.

Table 76. Effects of information told consumers and connective tissue levels on acceptability of restructured steaks.*

		Connective tissue levels		
Information told consumers	Acceptability	Extra high	High	Low
Told product was intact muscle steak--asked to indicate desirable characteristics	Very acceptable	32.7	20.4	12.2
	Just acceptable	59.2	63.3	42.9
	Not acceptable	8.2	16.3	44.9
Told product was restructured steak--asked to indicate desirable characteristics	Very acceptable	18.0	8.2	8.0
	Just acceptable	70.0	69.4	56.0
	Not acceptable	12.0	22.4	36.0
Told product was intact muscle steak--asked to indicate undesirable characteristics	Very acceptable	29.4	29.4	7.8
	Just acceptable	68.6	60.8	62.8
	Not acceptable	2.0	9.8	29.4
Told product was restructured steak--asked to indicate undesirable characteristics	Very acceptable	38.8	28.0	24.0
	Just acceptable	53.1	54.0	50.0
	Not acceptable	8.2	18.0	26.0

*Values are percentage values of frequencies indicated within connective tissue level and information told consumer's category.

Table 77. Effects of consumers level of beef consumption at home and connective tissue levels on consumers acceptability of restructured steaks.*

Times/week beef consumed at home	Acceptability	Connective tissue levels: Extra high	High	Low
2 or less	Very acceptable	37.5	27.3	20.0
	Just acceptable	62.5	63.6	70.0
	Not acceptable	0.0	9.1	10.0
Over 2 to 4 inclusive	Very acceptable	10.0	26.7	5.6
	Just acceptable	80.0	60.0	72.2
	Not acceptable	10.0	13.3	22.2
Over 4	Very acceptable	41.7	0.0	15.8
	Just acceptable	50.0	90.9	73.7
	Not acceptable	8.3	9.1	10.5
Chi-square, probability		6.9, P=.14	4.3, P=.36	2.3, P=.67

*Values are percentage values of frequencies indicated within times beef consumed per week and connective tissue level. Different groups evaluated each connective tissue level.

Table 78. Effects of factors that consumers like least about beef and connective tissue levels in restructured steaks on consumers acceptability of restructured steaks.*

Factors consumers like least about beef	Acceptability	Connective tissue levels		
		Extra high	High	Low
Gristle	Very acceptable	40.0	36.4	0.0
	Just acceptable	50.0	54.6	100.0
	Not acceptable	10.0	9.1	0.0
Texture	Very acceptable	20.8	10.0	17.6
	Just acceptable	70.8	85.0	64.7
	Not acceptable	8.3	5.0	17.6
Excess fat	Very acceptable	0.0	22.2	8.3
	Just acceptable	100.0	66.7	75.0
	Not accetpable	0.0	11.1	16.7
Other	Very acceptable	18.2	25.0	8.3
	Just acceptable	72.7	50.0	75.0
	Not acceptable	9.1	25.0	16.7
Chi-square, probability		4.4, P=.62	6.9, P=.46	2.3, P=.89

*Values are percentage values of frequencies indicated within factors, what consumers like least about beef and connective tissue levels. Different groups evaluated each connective tissue level.

Data given in Table 79 indicates that consumers who consider gristle as the factor they like least in beef felt that the levels of gristle detected in beef previously consumed was about equivalent when compared to any of the three products being tested. This finding would shed some serious doubt on consumers perception of gristle and what they consider as gristle in a product; especially when compared to the results found for consumers who feel that texture and excess fat are the most disliked factors in beef. Perhaps consumers can relate better to gristle when considering texture and tenderness.

Desirability criteria for restructured steaks varying in connective tissue as influenced by weekly beef consumption is provided in Table 80. None of the comparisons were statistically ($P>.05$) significant. Beef consumption volume did not affect consumers opinions of these products. In fact, there wasn't a great deal of difference among the three treatments in the distribution of responses for desirable characteristics.

Instron values (not in tabular form) were as follows: peak shear force (kg) = 22.1 for extra high, 14.6 for high, 14.3 for regular and 15.0 for low; Newtons/cm^2 = 25.8 for extra high, 15.9 for high, 16.3 for regular and 16.3 for low. In both cases, the only significant difference ($P<.05$) was the extra high connective tissue steaks vs the other three treatments. Cooking losses with appropriate statistical superscripts were: extra high = 32.4^a, high = 27.4^b, regular = 31.7^b, low = 27.7^a. Total collagen values (mg/g wet basis) were 16.4, 12.6 and 9.4 for extra high, high and low connective tissue steaks, respectively.

Table 79. Effects of factors that consumers like least about beef on detection of gristle in restructured steaks made to have various levels of connective tissue.*

Level of connective tissue	Category that consumers liked least about beef when eating it	Compared to beef you have previously consumed, was the amount of gristle...		
		More	The same	Less
Extra high	Gristle	16.7	66.7	16.7
" "	Texture	55.6	22.2	22.2
" "	Excess fat	69.2	15.4	15.4
" "	Other	50.0	25.0	50.0
High	Gristle	16.7	33.3	50.0
"	Texture	33.3	27.8	38.9
"	Excess fat	30.8	23.1	46.2
"	Other	50.0	37.5	12.5
Low	Gristle	16.7	66.7	16.7
"	Texture	16.7	55.6	27.8
"	Excess fat	7.7	46.2	46.2
"	Other	25.0	25.0	50.0

*Values are the percentage values of frequencies within least liked category with levels of connective tissue. Same group of consumers evaluated all three products.

Table 80. Effects of connective tissue levels and consumers level of beef consumption at home on response to desirable characteristics of restructured steaks when told they were intact muscle steaks.*

Times/week beef consumed at home	Characteristic	Connective tissue levels: Extra high	High	Low
2 or less	Low amount of gristle	0.0	3.2	2.4
	Texture, tenderness, firmness	29.7	29.0	29.3
	Juiciness	13.5	9.7	17.1
	Flavor, aroma	29.7	29.0	29.3
	Leanness	10.8	6.4	7.3
	Appearance	16.2	22.6	14.6
Over 2 to 4 inclusive	Low amount of gristle	2.3	4.4	3.6
	Texture, tenderness, firmness	38.6	41.3	28.6
	Juiciness	2.3	15.2	12.5
	Flavor, aroma	36.4	30.4	41.1
	Leanness	11.4	2.2	3.6
	Appearance	9.1	6.5	10.7
Over 4	Low amount of gristle	0.0	0.0	0.0
	Texture, tenderness, firmness	38.9	31.6	31.2
	Juiciness	5.6	15.8	9.4
	Flavor, aroma	38.9	26.3	40.6
	Leanness	0.0	5.3	0.0
	Appearance	16.7	21.0	18.8
	Chi-square, probability,	8.8, P=.55	7.1, P=.71	6.5, P=.77

*Values are percentage values of frequencies indicated within connective tissue levels and times/week.

Conclusions

Generally, these various consumer tests do not indicate very broad differences in desirability characteristics and acceptability between the various levels of connective tissue employed in the steaks. Texture profile, Instron and hydroxyproline evaluations indicate that perhaps the differences in connective tissue in these products are really not large enough to be accurately perceived by consumers; although the protocol in trimming certainly should have created more differences. However, there were some indications that consumers may have broadly differing opinions on what "gristle" is in these types of products. They did appear to confuse it with texture, although gristle does influence texture. Consumers who consider gristle as a major undesirable feature in beef seemed to be better able to separate the various treatments on the basis of gristle. Also, consumers who thought they were evaluating intact muscle steaks rather than restructured steaks, separated the treatments more logically on the basis of gristle. Serving the samples as strips, which required cutting with a knife, seemed to improve consumer's abilities to separate steaks on the basis of gristle. Steaks made to have low levels of connective tissue may have some problems with flavor and appearance. Finally, overall, large differences between age groups and sex in terms of their response to the steaks were not apparent.

EFFECTS OF TEMPERATURE AND BLENDING TIME DURING PROCESSING ON TEXTURE PROFILE PANEL, INSTRON AND COOKING PROPERTIES

Introduction

It is quite conceivable that various procedures or criteria inherent in processing, such as blending time and meat temperature at the time of flaking, can impart changes in the texture of restructured meat products. Several studies have been previously conducted in this area. With pork, Chesney, et al. (1978) found that a flaking temperature of 2.2° C produced higher shear values and more desirable cohesion than product flaked at -5.6° C. The warmer temperature in flaking also produced less cooking loss and higher juiciness scores. Previous work, Popenhagen, et al. (1973), on pork products using these same two temperatures showed higher juiciness, cohesiveness, overall acceptability and less cooking loss in meat.

Several studies (Booren, et al., 1981ab; Coon, et al., 1983) have compared 0, 6 12 and 18 min of mixing in the manufacture of restructured beef steaks. Booren, et al. (1981b) found improved tenderness with longer mixing times as well as increased juiciness and flavor. However, Coon, et al. (1983) found longer mixing times to produce increased resistence to breaking in Instron analyses. Mixing times of 0, 8, 16 and 24 min were compared in a study by Booren, et al. (1981). They found lower cooking losses after 24 min with increased tenderness and bind at 16 min. Durland, et al. (1982) found mixing times of 0, 5, 10 and 15 min to have no influence on various sensory and Instron measures of texture.

Materials and Methods

Again, USDA Choice, Yield Grade 2 and 3 boneless chuck meat was used in this study. Four different flaking temperatures were used. These were

28°, 34°, 40° F and a fourth treatment where 40° F was reduced to 34° F just prior to flaking by the addition of dry ice. Flaked meats from each of the four temperatures were then divided into three mixing times of 4, 8 and 16 min prior to stuffing. Other processing variables and procedures were those previously identified in other sections of this report.

Cooking procedures for steaks have previously been described. Samples were subjected to texture profile, Instron and cooking evaluations.

Results and Discussion

Raw material temperatures during various processing steps are given in Table 81a. Tempering procedures to achieve 28° F were quite successful (29° F), but for 40° F, produced a 43° F beef temperature. The effort to reduce the 40° F meat to 34° F with dry ice was successful. However, this product was more susceptible to temperature rise during blending than the other treatments. The 34° F product (actually 32° F at the time of flaking) rose to 43° F in 16 min mixed product.

Blending time (with the exception of interactions with temperature) exerted a significant influence ($P<0.05$) on only one texture profile panel characteristic - fibrousness (Table 81b). Chuck muscle blended for 4 min produced steaks that were evaluated as more fibrous than those produced from 8 and 16 min of mixing. Data pertaining to fragmentation also revealed few differences attributable to blending time (Table 82).

Cooking times (min/g) were longer for steaks derived from materials mixed for 8 min compared to 4 and 16 min of mixing (Table 83). A very consistent trend was found for less steak diameter shrinkage in cooking as raw material mixing increased. Also, 16 min of mixing produced lower

Table 81a. Product temperatures (°F) during processing.

	Temperature, °F			
Processing step	Dry ice	28	34	40
Prior to flaking	40.0	29.0	32.0	40.0
After flaking	34.0	30.0	37.0	43.0
After 4 min mixing	38.0	31.0	40.0	44.0
After 8 min mixing	38.0	34.0	40.0	44.0
After 16 min mixing	40.0	34.0	43.0	46.0
After stuffing for 4 min mixed product	40.0	36.0	40.0	45.0
After stuffing for 8 min mixed product	40.0	36.0	42.0	45.0
After stuffing for 16 min mixed product	42.0	40.0	43.0	46.0

Table 81b. Effects of blending time on texture profile panel scores.

Characteristic[a]	Blending time, min 4	8	16
Visual			
Fibrousness	7.2 ± 2.4[b]	5.6 ± 1.4[c]	5.7 ± 1.1[c]
Partial compression			
Springiness	9.5 ± 1.4	10.2 ± 1.2	10.1 ± 1.6
First bite			
Hardness	7.1 ± 1.2	7.2 ± 2.0	7.2 ± 1.9
Cohesiveness	9.7 ± 1.7	9.5 ± 2.0	9.8 ± 1.8
Uniformity	11.5 ± 1.3	11.1 ± 1.4	11.4 ± 1.2
Mastication			
Juiciness	7.0 ± 1.2	7.3 ± 1.1	7.0 ± 1.4
Size of chewed particles	9.3 ± 1.8	9.5 ± 1.7	9.3 ± 2.0
Cohesiveness of mass	9.3 ± 1.7	9.5 ± 2.1	8.6 ± 2.2
Uniformity of mass	10.4 ± 1.9	10.9 ± 1.9	10.7 ± 2.1
Gristle	1.7 ± 1.3	1.9 ± 1.7	1.9 ± 1.5
Webbed tissue	3.2 ± 2.6	3.0 ± 2.5	2.6 ± 1.8
Overall gristle	2.0 ± 1.7	2.5 ± 2.3	2.5 ± 1.8
Overall webbed tissue	3.0 ± 2.1	2.8 ± 2.0	2.7 ± 1.9
Number of chews	53.0 ± 6.6	53.4 ± 8.4	54.6 ± 8.4
After swallow			
Tooth pack	2.5 ± 1.1	2.8 ± 1.5	2.4 ± .91

[a]Definitions for the various characteristics are given in Appendix Table 4.

[b,c]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Table 82. Frequency of fragmentation categories in restructured beef steaks according to blending time.

Fragmentation category[a]	Blending time, min 4	8	16
Complete shearing	25.7	35.5	31.9
Incomplete shearing--threads	35.7	32.3	39.1
Incomplete shearing--crust	22.9	16.1	15.9
Complete crumbly separation	1.4	0.0	0.0
Incomplete crumbly separation--threads	1.4	0.0	0.0
Incomplete crumbly separation--crust	0.0	0.0	0.0
Compacts along shear line	2.9	1.6	2.9
Chunky and complete separation	0.0	1.6	2.9
Incomplete chunky separation--threads	2.9	6.4	1.4
Incomplete chunky separation--crust	0.0	0.0	0.0
Layered separation	7.1	3.2	4.3
Other	0.0	3.2	1.4

[a]Values are percentage frequencies of sample evaluations within blending times that were classified into the fragmentation categories.

Table 83. Effects of blending time on cooking properties and Instron values of restructured beef steaks.

Characteristic	Blending time, min 4	8	16
Cooking properties			
Degree of doneness score	3.3 ± 0.6	3.4 ± 0.5	3.3 ± 0.6
Cooking time, min/g	0.16 ± 0.01[b]	0.17 ± 0.01[a]	0.16 ± 0.03[b]
Change in steak thickness from raw to cooked, %	4.4 ± 6.3	3.8 ± 8.2	2.8 ± 6.5
Change in steak diameter from raw to cooked, %	-17.1 ± 2.8[a]	-15.6 ± 3.8[b]	-13.9 ± 2.6[c]
Instron			
Maximum shear force, kg	14.7 ± 1.5[a]	14.0 ± 1.5[ab]	13.7 ± 1.5[b]
Newtons/cm^2	16.8 ± 1.7	16.2 ± 1.9	16.0 ± 2.0

[a,b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

shear force values than 4 min of mixing. However, when considering the dimensional changes from cooking (Newtons) these differences were nonsignificant (P>0.05). Booren, et al. (1981ab) also found reduced Instron shear force values with increase in mixing time between 0, 6, 12 and 18 min.

Effects of beef temperature at the time of flaking on texture profile panel evaluations are presented in Table 84. The lowest temperature of beef produced less distortion than was noted for 34° F product. The 34° F product also had less springiness than dry ice and 28° F product.

Fragmentation frequencies do not show many distinct differences among the treatments (Table 85). The highest temperature in mixing (40° F) had the highest frequency of complete shearing with the lowest incidence of crust. This would imply perhaps slightly less salt soluble protein extraction at that temperature. However, the differences in fragmentation are not great, with the vast majority of classifications being "shearing" of some sort regardless of blending temperature.

Degree of doneness in cooked samples was more rare for steaks processed from beef flaked at 34° F compared to the other temperatures. Steaks made from 40° F beef underwent the least swelling during cooking, while steaks fabricated from 28° F beef had more diameter shrinkage than the other treatments. Instron values followed no particular trend with 28° F steaks having higher shear and Newton values, while dry ice and 34° F product had the lowest values. Chesney, et al. (1978) found higher shear values in product made from 2.2° C flaked pork vs -5.6° C flaked pork.

Interactions (P<0.05) for various texture profile panel scores and cooking loss are given in Table 87. While 40° F generally produced more macro distortion regardless of blending time, the other temperatures

Table 84. Effects of temperature during flaking on texture profile panel scores.

	Flaking temperature, °F			
Characteristic[a]	Dry ice	28	34	40
Visual				
Micro distortion	$4.1 \pm .78^{bc}$	$3.5 \pm .78^{c}$	$4.3 \pm .82^{b}$	4.0 ± 1.4^{bc}
Fibrousness	6.5 ± 2.3	6.3 ± 1.2	6.2 ± 1.2	5.8 ± 1.7
Partial compression				
Springiness	$10.9 \pm .66^{b}$	10.3 ± 1.2^{bc}	8.8 ± 1.5^{d}	9.6 ± 1.8^{cd}
First bite				
Hardness	7.5 ± 1.0	7.7 ± 1.9	6.4 ± 1.8	6.9 ± 2.0
Cohesiveness	10.1 ± 1.2	10.0 ± 1.7	8.9 ± 2.0	9.4 ± 2.0
Uniformity	11.7 ± 1.3	11.2 ± 1.3	11.1 ± 1.7	11.3 ± 1.2
Mastication				
Juiciness	$7.4 \pm .75$	6.9 ± 1.2	7.2 ± 1.4	7.0 ± 1.5
Size of chewed particles	10.2 ± 1.5^{b}	9.4 ± 1.9^{c}	8.6 ± 1.9^{d}	9.1 ± 2.0^{cd}
Cohesiveness of mass	9.2 ± 1.9	8.9 ± 2.4	9.6 ± 1.6	8.7 ± 2.0
Uniformity of mass	10.8 ± 2.2	9.9 ± 1.7	10.9 ± 1.7	11.2 ± 2.1
Gristle	1.9 ± 1.6	2.3 ± 1.4	1.4 ± 1.5	1.8 ± 1.5
Webbed tissue	2.9 ± 2.1	3.3 ± 2.4	3.5 ± 3.1	2.1 ± 1.4
Overall gristle	2.4 ± 2.2	2.8 ± 1.7	1.6 ± 1.8	2.4 ± 2.0
Overall webbed tissue	2.4 ± 1.7^{c}	3.6 ± 2.4^{b}	3.4 ± 2.4^{b}	2.0 ± 1.2^{c}
Number of chews	54.3 ± 7.7	57.4 ± 6.3	49.7 ± 7.6	52.9 ± 9.4
After swallow				
Tooth pack	2.5 ± 1.1^{bc}	3.1 ± 1.4^{b}	2.5 ± 1.4^{bc}	$2.2 \pm .74^{c}$

[a]Definitions for the various characteristics are given in Appendix Table 4.

[b,c,d]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 85. Frequency of fragmentation categories in restructured beef steaks according to flaking temperature.

	Flaking temperature °F			
Fragmentation category[a]	Dry ice	28	34	40
Complete shearing	27.3	22.9	30.4	39.6
Incomplete shearing--threads	27.3	42.3	39.1	35.4
Incomplete shearing--crust	27.3	21.1	15.2	8.3
Complete crumbly separation	1.8	0.0	0.0	0.0
Incomplete crumbly separation--threads	0.0	0.0	2.2	0.0
Incomplete crumbly separation--crust	0.0	0.0	0.0	0.0
Compacts along shear line	1.8	1.9	2.2	4.2
Chunky and complete separation	1.8	0.0	0.0	4.2
Incomplete chunky separation--threads	5.4	3.8	0.0	4.2
Incomplete chunky separation--crust	0.0	0.0	0.0	0.0
Layered separation	3.6	1.9	10.9	4.2
Other	3.6	1.9	0.0	0.0

[a]Values are percentage frequencies of sample evaluations within blending temperatures that were classified into the fragmentation categories.

Table 86. Effects of temperature during flaking on cooking properties and Instron values of restructured beef steaks.

Characteristic	Flaking temperature, ° F: Dry ice	28	34	40
Cooking properties				
Degree of doneness score	3.3 ± 0.7^{b}	3.2 ± 0.5^{b}	3.8 ± 0.5^{a}	3.0 ± 0.5^{b}
Cooking time, min/g	0.15 ± 0.01^{b}	0.17 ± 0.01^{a}	0.16 ± 0.03^{b}	0.16 ± 0.01^{ab}
Change in steak thickness from raw to cooked, %	3.6 ± 6.0^{a}	5.3 ± 7.1^{a}	6.6 ± 5.9^{a}	0.7 ± 8.7^{b}
Change in steak diameter from raw to cooked, %	-14.1 ± 2.9^{b}	-17.3 ± 4.0^{a}	-15.3 ± 2.8^{b}	-15.5 ± 2.7^{b}
Instron				
Maximum shear force, kg	13.1 ± 1.2^{c}	15.6 ± 1.8^{a}	13.6 ± 1.8^{bc}	14.1 ± 1.2^{b}
Newtons/cm^2	15.0 ± 1.6^{c}	18.3 ± 1.9^{a}	15.0 ± 1.9^{c}	17.0 ± 2.1^{b}

[a,b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 87. Interaction of temperature during flaking and blending time on texture profile panel scores and cooking loss.

Blending time, min	Flaking temperature, °F	Characteristic[a] Macro distortion	Moisture release	Mouth coating	Cooking loss, %
4	Dry ice	6.7 ± 1.4	5.8 ± 2.2	3.6 ± 1.3	33.9
4	28	3.6 ± .69	6.1 ± 1.9	4.4 ± .87	30.4
4	34	4.9 ± 1.3	6.4 ± 1.7	5.5 ± 1.5	28.4
4	40	5.1 ± 1.0	7.2 ± 2.0	5.4 ± 2.3	31.3
8	Dry ice	4.5 ± .84	6.8 ± 1.9	4.5 ± 1.6	28.3
8	28	2.8 ± .84	6.3 ± 1.8	5.0 ± 1.4	30.7
8	34	3.7 ± .81	6.9 ± 1.1	4.4 ± 1.5	27.7
8	40	4.2 ± 1.4	6.3 ± 2.0	4.5 ± 1.1	31.7
16	Dry ice	3.6 ± .98	8.2 ± 2.4	5.6 ± 3.5	29.4
16	28	5.9 ± 1.9	6.6 ± 2.4	4.3 ± 1.4	30.9
16	34	6.1 ± 1.5	6.0 ± 1.7	4.4 ± 2.3	28.7
16	40	6.2 ± 1.2	5.9 ± 1.8	4.1 ± 2.3	36.6

[a]Definitions for the various characteristics are given in Appendix Table 4.

displayed no consistent trend respective to macro distortion. With the lower flaking temperatures, increased blending time produced higher moisture release, while the opposite was true for the higher flaking temperature. A major factor contributing to the significant interaction for cooking loss was the high losses obtained from steaks made from beef chucks subjected to a 40° F temperature and 16 min of mixing.

Conclusions

The blending times and flaking temperatures used in this study generally did not greatly influence the textural properties of the resultant restructured steaks. Increased blending times resulted in less diameter shrinkage of steaks. Steaks processed from beef flaked at 40° F had very little swelling during cooking.

EFFECTS OF A WIDE ARRAY OF COMITROL HEAD SIZES ON TEXTURE PROFILE PANEL, INSTRON AND COOKING PROPERTIES OF RESTRUCTURED STEAKS

Introduction

In this project, variations in Comitrol head size (particle size, flake size) have been investigated usually in conjunction with some other variable. Flake size has been the factor that has shown the biggest difference and probably most consistent differences in textural properties. This study was designed to evaluate, in addition to the standard Comitrol head sizes previously used, some additional head sizes.

Materials and Methods

USDA Choice, Yield Grade 2 and 3 chuck meat was used. Ten different Comitrol head sizes were used to produce variations in flake size (1610, 1614, 1620, 1628, 750, 510, 390, 270, 180, 060).

Steaks were cooked to an internal temperature of 70° C. Texture profile panel, Instron and cooking evaluations have been previously mentioned.

Results and Discussion

Differences due to head size were found for macro distortion, but they do not necessarily relate in a linear manner (Table 88). Steaks made from the 390 head had the least macro distortion, while the 060 head produced the greatest distortion. Micro distortion followed more of a logical pattern respective to head size; more with larger flake size steaks, less with smaller flake size steaks. Likewise, visual detection of fibrousness decreased as particle sizes became smaller. However, the differences were not significant ($P>0.05$) over the range between 1628 and 060.

Table 88. Effects of new Comitrol head sizes on visual and partial compression texture profile panel scores for restructured beef steak.

Comitrol head size	Characteristic[a] Macro distortion	Micro distortion	Fibrousness	Springiness
1610	5.9 ± 1.7[bc]	6.5 ± 1.0[b]	8.5 ± 0.5[b]	9.8 ± 1.1
1614	6.0 ± 0.6[bc]	5.5 ± 0.8[bc]	7.8 ± 1.1[bc]	10.7 ± 1.1
1620	5.4 ± 1.8[cd]	4.9 ± 1.4[cd]	7.5 ± 1.3[bc]	10.4 ± 1.8
1628	5.1 ± 0.9[cde]	4.6 ± 1.0[cde]	6.1 ± 0.9[cd]	10.8 ± 1.1
750	5.0 ± 1.8[cde]	5.3 ± 1.6[bc]	6.1 ± 2.1[cd]	10.8 ± 1.8
510	3.8 ± 0.8[e]	4.0 ± 1.1[def]	6.7 ± 0.8[bc]	10.4 ± 0.8
390	4.2 ± 0.8[de]	4.3 ± 1.3[def]	6.1 ± 1.4[cd]	10.6 ± 1.2
270	4.2 ± 1.4[de]	3.3 ± 0.8[ef]	4.7 ± 1.6[d]	11.5 ± 0.8
180	5.0 ± 1.0[cde]	3.5 ± 1.1[ef]	4.6 ± 1.3[d]	11.0 ± 1.2
060	6.7 ± 2.7[b]	3.9 ± 1.3[def]	4.4 ± 1.1[d]	9.4 ± 1.7

[a]Definitions for the various characteristics are given in Appendix Table 4.

[b,c,d,e,f]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

First bite characteristics for the restructured steaks are given in Table 89. Hardness generally decreased and uniformity of first bite increased as flake sizes in the steaks became smaller. Steak samples from the 750 head were rated as similar in first bite cohesiveness to the 1600 head sizes.

A very definite trend was evident respective to the presence of complete shearing during fragmentation evaluation (Table 90). Steaks made with small flakes of beef had more complete shearing and less incomplete chunky separation. Incomplete shearing seemed to be greatest in steaks made with the intermediate size heads.

Juiciness values following 7 chews differed among the treatments, but no particular trends were evident (Table 91). Surprisingly, very few differences were found for size of chewed particles. Cohesiveness of the mass decreased and uniformity of the mass increased as flake sizes became smaller. A continuation of the mastication properties is presented in Table 92. Connective tissue properties in terms of detectable volume and number of chews decreased as flaked meat particles became smaller in restructured steaks. Values for the 1628 for connective tissue components were similar to the 390 and smaller heads. Apparently, the addition of more cutting edges (even though the horizontal flake particle dimension is larger) is effective in "shredding" or reducing the detection of connective tissue in some manner.

Tooth pack and mouth coating were more evident in steaks from the larger head sizes (Table 93). Larger sizes of fat particles would also be present in steaks made from larger Comitrol heads and thus could possibly coat the mouth with fat more often.

Table 89. Effects of new Comitrol head sizes on first bite texture profile panel scores for restructured beef steaks.

Comitrol head size	Hardness	Cohesiveness	Moisture release	Uniformity
	Characteristic[a]			
1610	10.1 ± 1.8[b]	9.9 ± 1.3[bcd]	5.8 ± 1.0[de]	7.0 ± 2.3[f]
1614	9.4 ± 0.7[bc]	10.3 ± 0.8[bc]	6.4 ± 1.0[bcd]	10.0 ± 1.9[e]
1620	9.5 ± 1.0[bc]	9.9 ± 1.7[bcd]	7.0 ± 1.1[bc]	9.7 ± 1.7[e]
1628	7.1 ± 1.3[fg]	9.1 ± 1.5[cd]	5.8 ± 1.3[de]	11.8 ± 0.9[cd]
750	9.0 ± 2.4[cd]	10.7 ± 0.8[b]	5.6 ± 1.0[de]	10.0 ± 2.2[e]
510	8.6 ± 1.1[cde]	10.0 ± 0.7[bcd]	6.3 ± 0.9[bcd]	11.2 ± 1.0[d]
390	7.9 ± 1.4[def]	8.6 ± 1.4[d]	6.1 ± 1.2[cde]	11.3 ± 1.3[d]
270	7.6 ± 1.1[efg]	9.3 ± 0.6[bcd]	7.2 ± 1.2[b]	12.6 ± 0.7[bc]
180	7.6 ± 0.5[efg]	9.4 ± 1.6[bcd]	5.8 ± 1.3[de]	12.8 ± 1.2[bc]
060	6.6 ± 1.5[g]	9.3 ± 0.8[bcd]	5.1 ± 1.9[e]	13.5 ± 0.4[b]

[a]Definitions for the various characteristics are given in Appendix Table 4.

[b,c,d,e,f,g]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Table 90. Frequency of fragmentation categories in restructured beef steaks according to new Comitrol head sizes.

Fragmentation category[a]	Comitrol head size									
	1610	1614	1620	1628	750	510	390	270	180	060
Complete shearing	0.0	11.1	13.3	28.6	9.1	15.4	32.0	45.8	50.0	75.0
Incomplete shearing--threads	15.6	48.2	26.7	39.2	45.4	53.8	32.0	33.3	29.2	8.3
Incomplete shearing--crust	6.2	11.1	10.0	14.3	33.3	15.4	12.0	20.8	20.8	16.7
Complete crumbly separation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Incomplete crumbly separation--threads	0.0	0.0	0.0	3.6	0.0	7.7	4.0	0.0	0.0	0.0
Incomplete crumbly separation--crust	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Compacts along shear line	6.2	3.7	6.7	7.1	0.0	0.0	0.0	0.0	0.0	0.0
Chunky and complete separation	0.0	0.0	0.0	0.0	3.0	0.0	4.0	0.0	0.0	0.0
Incomplete chunky separation--threads	37.5	11.1	26.7	3.6	9.1	3.8	16.0	0.0	0.0	0.0
Incomplete chunky separation--crust	18.8	3.7	16.7	3.6	0.0	3.8	0.0	0.0	0.0	0.0
Layered separation	3.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	12.5	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Values are percentage frequencies of sample evaluations within Comitrol head sizes that were classified into the fragmentation categories.

Table 91. Effects of new Comitrol head sizes on mastication scores from texture profile panel evaluations of restructured beef steaks--Part A.

Comitrol head size	Juiciness	Size of chewed particles	Cohesiveness of the mass	Uniformity of the mass
	Characteristics[a]			
1610	$7.5 \pm .82^{bc}$	$10.7 \pm .78^{b}$	10.8 ± 1.7^{b}	7.6 ± 1.4^{g}
1614	7.9 ± 1.3^{b}	10.9 ± 1.0^{b}	$9.8 \pm .88^{bcd}$	10.0 ± 1.6^{ef}
1620	7.7 ± 1.0^{bc}	$10.4 \pm .37^{bc}$	$10.5 \pm .96^{bc}$	9.6 ± 1.2^{f}
1628	7.7 ± 1.1^{bc}	$9.6 \pm .61^{cd}$	7.6 ± 1.3^{ef}	$12.0 \pm .96^{cd}$
750	6.6 ± 1.2^{cd}	10.0 ± 1.2^{bcd}	$9.4 \pm .54^{de}$	9.6 ± 2.5^{f}
510	$7.4 \pm .68^{bc}$	$10.8 \pm .73^{b}$	8.9 ± 1.2^{de}	11.1 ± 1.4^{ef}
390	6.9 ± 1.8^{bc}	10.6 ± 1.4^{b}	7.5 ± 1.6^{f}	$10.6 \pm .92^{ef}$
270	8.0 ± 1.4^{b}	$10.7 \pm .93^{b}$	7.2 ± 1.8^{f}	$12.1 \pm .94^{cd}$
180	6.5 ± 1.6^{cd}	10.0 ± 1.3^{bcd}	7.1 ± 2.4^{f}	$12.9 \pm .88^{bc}$
0.60	5.6 ± 1.1^{d}	$9.4 \pm .64^{d}$	6.4 ± 2.0^{f}	$13.8 \pm .60^{b}$

[a]Definitions for the various characteristics are given in Appendix Table 4.

[b,c,d,e,f,g]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Table 92. Effects of new Comitrol head sizes on mastication scores from texture profile panel evaluations of restructured beef steaks--Part B.

Comitrol head size	Characteristic[a]				
	Gristle	Webbed tissue	Overall gristle	Overall webbed tissue	Number of chews
1610	4.7 ± 1.6^{b}	$4.5 \pm .89^{b}$	5.5 ± 1.9^{b}	4.7 ± 0.6^{b}	70.9 ± 8.0^{b}
1614	3.1 ± 2.1^{c}	3.6 ± 1.2^{bcd}	3.9 ± 1.8^{c}	3.5 ± 2.4^{bcd}	61.6 ± 6.1^{cd}
1620	3.1 ± 2.1^{c}	3.7 ± 1.0^{bc}	3.3 ± 0.8^{cd}	3.6 ± 0.8^{bc}	63.9 ± 7.4^{c}
1628	$0.6 \pm .70^{e}$	1.5 ± 1.3^{fg}	1.1 ± 1.1^{efg}	1.5 ± 1.5^{ef}	55.0 ± 8.0^{def}
750	$1.7 \pm .98^{d}$	3.0 ± 1.4^{cde}	2.0 ± 1.2^{def}	3.3 ± 1.3^{cd}	58.1 ± 5.6^{cde}
510	$1.9 \pm .60^{d}$	$2.5 \pm .83^{efg}$	2.3 ± 1.3^{de}	2.4 ± 1.4^{de}	52.5 ± 6.5^{ef}
390	$1.7 \pm .49^{d}$	$1.9 \pm .33^{ef}$	2.2 ± 1.0^{de}	1.8 ± 0.5^{ef}	57.7 ± 8.6^{cde}
270	$0.3 \pm .34^{e}$	$0.6 \pm .27^{gh}$	0.9 ± 0.7^{fg}	0.7 ± 0.3^{fg}	49.8 ± 6.4^{f}
180	0.1 ± 1.8^{e}	$0.4 \pm .34^{gh}$	0.1 ± 0.2^{g}	0.3 ± 0.2^{g}	51.2 ± 4.7^{ef}
060	$0.1 \pm .16^{e}$	$0.4 \pm .53^{h}$	0.1 ± 0.2^{g}	0.3 ± 0.1^{g}	48.7 ± 4.3^{f}

[a] Definitions for the various characteristics are given in Appendix Table 4.

[b,c,d,e,f,g,h] Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Table 93. Effects of new Comitrol head sizes on after swallow scores from texture profile panel scores for restructured beef steaks.

Comitrol head size	Characteristic: Tooth pack	Characteristic: Mouth coating
1610	$3.6 \pm .80^{a}$	5.0 ± 1.3^{abc}
1614	3.6 ± 1.8^{a}	5.2 ± 1.4^{ab}
1620	$3.6 \pm .65^{a}$	$5.4 \pm .93^{a}$
1628	$2.4 \pm .74^{bc}$	4.0 ± 2.2^{dc}
750	3.2 ± 1.0^{ab}	4.6 ± 1.5^{abc}
510	$2.7 \pm .73^{bc}$	4.1 ± 1.3^{bcd}
390	$2.8 \pm .57^{bc}$	$4.2 \pm .63^{bcd}$
270	$2.3 \pm .92^{dc}$	4.2 ± 1.0^{bcd}
180	$1.6 \pm .26^{d}$	$3.3 \pm .93^{de}$
060	$1.6 \pm .60^{d}$	$2.8 \pm .91^{e}$

[a,b,c,d,e]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Steaks made with the 750 and 510 heads had a more well done cooked appearance than steaks made from the 270 and 180 heads (Table 94). Cooking times appeared to be longest for steaks from intermediate size Comitrol heads. Cooking loss differences were apparent, but followed no particular trend in terms of flake size. Some rather dramatic differences were noted for Instron values attributable to flake size. First, steaks made from the 1610 head had more resistance to shear than any other treatment ($P<0.05$). However, the other 1600 head sizes yielded shear values very similar to the smaller head sizes (270, 180, 060). The 750, 510 and 390 heads yielded shear values in between the 1610 and 1614 heads. These results are very interesting in comparison with the texture profile panel values. There were no textural properties that had differences between head sizes similar to these Instron values. While this study was one of the later ones of this project, it serves to indicate that from a sensory approach, we still haven't identified all the sample properties that are expressed in an instrumental approach. With the exception of texture profile panel, connective tissue and Instron values, standard deviations don't deviate much in size from one treatment to another. These standard deviations have the effects of panelists removed in the case of texture profile panel results.

Conclusions

This study comparing new and vastly different Comitrol heads for flaking meat produced rather substantial differences in texture profile panel and Instron results. Generally, steaks with large flake sizes had more fibrousness, greater first bite hardness, less first bite uniformity, less complete and incomplete shearing after two bites, more cohesiveness

Table 94. Effects of new Comitrol head sizes on cooking properties and Instron values for restructured beef steaks.

	Characteristic				
Comitrol head size	Degree of doneness	Cooking time min/g	Cooking loss, %	Maximum shear force, kg	Newtons/ cm^2
1610	$3.2 \pm .43^{bc}$	$.16 \pm .010^{bcd}$	26.5 ± 3.3^{bc}	53.4 ± 12.6^{a}	61.8 ± 14.6^{a}
1614	$3.1 \pm .36^{bc}$	$.16 \pm .009^{cde}$	25.5 ± 2.4^{c}	23.7 ± 5.4^{ef}	27.5 ± 6.6^{de}
1620	$3.3 \pm .47^{bc}$	$.15 \pm .009^{e}$	25.3 ± 1.3^{c}	21.8 ± 4.9^{f}	24.2 ± 5.9^{de}
1628	$3.1 \pm .66^{bc}$	$.17 \pm .009^{a}$	28.7 ± 4.1^{ab}	18.1 ± 3.4^{g}	21.0 ± 5.0^{e}
750	$3.0 \pm .13^{c}$	$.17 \pm .019^{ab}$	27.1 ± 3.6^{bc}	40.1 ± 8.9^{c}	43.7 ± 12.1^{c}
510	$2.9 \pm .18^{c}$	$.17 \pm .008^{abc}$	26.9 ± 1.6^{bc}	44.5 ± 7.1^{b}	51.2 ± 8.8^{b}
390	$3.1 \pm .27^{bc}$	$.17 \pm .009^{ab}$	28.6 ± 1.9^{ab}	33.9 ± 6.5^{d}	37.9 ± 9.4^{c}
270	$3.9 \pm .66^{a}$	$.16 \pm .012^{bcd}$	22.2 ± 3.2^{d}	26.8 ± 4.1^{e}	28.3 ± 3.9^{d}
180	$3.4 \pm .65^{b}$	$.16 \pm .003^{abc}$	26.8 ± 3.1^{bc}	24.6 ± 3.0^{ef}	27.2 ± 4.0^{d}
060	$2.9 \pm .43^{c}$	$.15 \pm .008^{de}$	29.4 ± 3.1^{a}	15.0 ± 2.4^{g}	18.4 ± 3.1^{e}

[a,b,c,d,e,f,g]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

of mass, less uniformity of mass and greater amounts of detectable connective tissue than steaks processed with smaller flake size heads. The 1628 head may be the head of choice for producing steak-like texture, but still effectively reducing detectable connective tissue. Instron values for the 1628 head were very similar to the 060 head. The 750 head seemed to produce textural properties closer to that of the 1610 head than has been observed in previous studies of this report involving these two head sizes.

USE OF PRERIGOR PRESSURIZED BEEF IN CHUNKED AND FORMED AND FLAKED AND FORMED BEEF STEAKS

Introduction

The use of hot boned beef for restructured beef steaks has been investigated in a couple of studies. Seideman, et al. (1982b) found hot boned beef to yield lower tenderness and less texture and flavor desirability compared to restructured steaks processed from cold boned beef. However, Huffman, et al. (1984) found no differences in flavor, texture and acceptability between restructured steaks made with hot boned vs those made with cold boned beef.

Prerigor pressurization of beef has been shown to have a marked improvement in tenderness (Kennick, et al., 1980). Emulsifying capacity of prerigor pressurized muscle has not been shown to differ much from nonpressurized beef (Elgasim, et al., 1982). Before this system achieves wide application in meats processing, additional benefits must be demonstrated. The intent of this study was to determine if textural and cooking properties of both restructured chunked and formed and flaked and formed steaks could be improved through prerigor pressurization.

Materials and Methods

Boneless *biceps femoris*, *semitendinosus*, *semimembranosus*, shoulder clod and inside chuck muscles were removed from both sides of one U.S. Utility carcass and from the right side of another U.S. Utility carcass immediately following slaughter. The prerigor pressurization process consisted of placing the muscles in vacuum packaged bags followed by

placing the muscles in a preheated (35° C) water-filled pressure chamber (30.48 cm in diameter and 60.96 cm long) and then applying 103.5 MNm^{-2} (15,000 lb/in^2) for 2 min. These muscles from the other side of the second carcass received no pressurization. These procedures were performed at Oregon State University. The muscles were frozen and shipped to U.S. Army Natick Laboratories for manufacture into restructured beef steaks.

For the chunked and formed steaks, excess fat was removed from the partially thawed muscles, emulsified and then used for later fat adjustment. The round and chuck muscles from one side that had received the pressurization treatment were mixed and used for the chunked and formed product. Three salt levels were used; 0.0, 0.25 and 0.50%. Following mixing, stuffing, freezing, tempering, reshaping and slicing, one-half the steaks in each treatment were vacuum packaged for frozen storage, while the remaining half were stacked, placed in a bag and then boxed for storage.

In the case of the flaked and formed steaks, product was processed from both pressurized and nonpressurized rounds and chucks. Restructured flaked and formed steaks were made from pressurized and nonpressurized round and chuck muscles (separately). Furthermore, pressurized round and chuck muscles were mixed with one of three salt levels (0.0, 0.25,, 0.50%) for comparison to chunked and formed product. Treatments were mixed to try and achieve the same degree of tackiness. Mixing times were 12 min for 0.0% NaCl, 10 min for 0.25% NaCl and 8 min for 0.50% NaCl. Again, after the final step of steak slicing, one-half of the steaks were vacuum packaged, while the other half were placed in bags and stored in boxes.

Steaks were subjected to texture profile, Instron and cooking evaluations.

Results and Discussion

Only one texture profile characteristic was affected independently (noninteraction) by pressurization vs nonpressurization (Table 95). First bite hardness was less in steaks from pressurized beef compared to steaks from nonpressurized beef. Many more textural properties were affected by raw material source (Table 96). Steaks manufactured from chucks were rated as more uniform in first bite and mass compared to those processed from rounds. Webbed tissue was less in steaks from chucks vs those of rounds. Fewer chews, less tooth pack and less mouth coating also characterized the steaks from chuck meat. Vacuum packaging (Table 97) resulted in a less fibrous appearance and more uniformity of mass in contrast to nonvacuum packaging.

The interaction ($P<0.05$) of raw material source and pressurization is presented in Table 98 for size of chewed particles in flaked and formed steaks. Round steaks from pressurized beef were evaluated as having a larger size to chewed pieces compared to nonpressurized round steaks. The opposite was true for chuck steaks. Pressurized vacuum packaged steaks had more detectable gristle compared to pressurized nonvacuum packaged steaks (Table 99). The opposite situation occurred for nonpressurized steaks. There is no reason to expect that packaging should cause any changes in the ability to detect gristle. Restructured round steaks placed in vacuum packaging was rated as having less cohesiveness of mass than round steaks placed in nonvacuum packaging (Table 100). However, the opposite occurred for restructured chuck steaks under vacuum and nonvacuum packaging.

Table 95. Effects of pre-rigor muscle pressurization on first bite hardness values for restructured beef steaks.

Pressurization	First bite hardness[a]
Pressurized	7.9 ± 1.6^{c}
Not pressurized	8.7 ± 1.3^{b}

[a]Definition for macro distortion given in Appendix Table 4.

[b,c]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Table 96. Effects of raw material source on texture profile panel scores for restructured beef steaks.

Characteristic[a]	Raw material source: Round	Chuck
Visual		
Fibrousness	7.1 ± 1.5	7.2 ± 1.5
Partial compression		
Springiness	10.1 ± 1.2	9.8 ± 1.5
First bite		
Hardness	8.6 ± 1.6	8.1 ± 1.3
Cohesiveness	9.7 ± 1.6	9.4 ± 1.3
Uniformity	10.3 ± 2.0[c]	11.6 ± 1.3[b]
Moisture release	6.0 ± 0.8	5.6 ± 1.2
Mastication		
Juiciness	7.1 ± 1.2	7.0 ± 1.0
Uniformity of mass	10.4 ± 1.9[c]	11.3 ± 1.4[b]
Gristle	1.6 ± 1.0	1.4 ± 1.4
Webbed tissue	3.3 ± 1.8[b]	2.3 ± 1.6[c]
Overall gristle	2.0 ± 1.5	1.6 ± 1.1
Overall webbed tissue	3.1 ± 1.6[b]	2.0 ± 1.4[c]
Number of chews	63.0 ± 10.4[b]	56.1 ± 7.8[c]
After swallow		
Tooth pack	3.6 ± 1.3[b]	2.8 ± 0.9[c]
Mouth coating	5.4 ± 1.1[b]	4.5 ± 1.2[c]

[a]Definitions for the various characteristics are given in Appendix Table 4.

[b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 97. Effects of packaging on texture profile panel scores for fibrousness and uniformity of the mass in restructured beef steaks.

Packaging system	Fibrousness[a]	Uniformity of mass[a]
Vacuum	6.7 ± 1.4^{c}	11.4 ± 1.4^{b}
Non vacuum	7.4 ± 1.6^{b}	10.4 ± 2.3^{c}

[a]Definitions for fibrousness and uniformity of mass given in Appendix Table 4.

[b,c]Means in the same column bearing different superscripts are significantly ($P < 0.05$) different.

Table 98. Interaction effects of raw material source and pre-rigor pressurization on texture profile panel scores for size of chewed particles in restructured beef steaks.

Raw material source	Pressurization	Size of chewed particles[a]
Round	Pressurized	9.2 ± 1.0
Round	Not pressurized	10.1 ± 1.0
Chuck	Pressurized	10.2 ± 0.9
Chuck	Not pressurized	9.8 ± 1.2

[a]Definition for size of chewed particles is given in Appendix Table 4.

Table 99. Interaction effects of pre-rigor pressurization and packaging system on texture profile panel scores for gristle in restructured beef steaks.

Pressurization	Packaging system	Gristle[a]
Pressurized	Vacuum	0.7 ± 0.7
Pressurized	Non vacuum	1.8 ± 1.3
Not pressurized	Vacuum	1.8 ± 0.9
Not pressurized	Non vacuum	1.3 ± 1.1

[a]Definition for gristle is given in Appendix Table 4.

Table 100. Interaction effects of raw material source and packaging system on texture profile panel scores for cohesiveness of the mass in restructured beef steaks.

Raw material source	Packaging system	Cohesiveness of mass[a]
Round	Vacuum	8.9 $\pm$ 0.9
Round	Non vacuum	9.7 $\pm$ 1.6
Chuck	Vacuum	10.0 $\pm$ 1.3
Chuck	Non vacuum	8.6 $\pm$ 1.8

[a]Definition for cohesiveness of mass is given in Appendix Table 4.

A three-way interaction involving raw material source, pressurization and packaging system for macro and micro distortion is presented in Table 101. In three out of four comparisons between vacuum and nonvacuum packaging, nonvacuum packaging created more macro and micro steak distortion. However, for nonpressurized round steaks, vacuum packaging produced more distortion than nonvacuum packaging.

Frequency distributions for pressurized and nonpressurized steaks are given in Table 102. No major trends or differences were detected. Frequency distributions for round vs chuck steaks are presented in Table 103. Restructured steaks from chucks were classified as having more complete and incomplete shearing. Round steaks had more incomplete chunky separation.

Restructured steaks fabricated from chuck muscles had lower shear and Newton values than steaks made from round muscles (Table 104). Data previously given in this report showed no difference between these two muscles.

Prerigor pressurization caused a slight decrease in steak width during cooking, while nonpressurization resulted in a slight increase in steak width (Table 105). Raw material source and pressurization were involved in a significant ($P<0.05$) interaction for degree of doneness and cooking time (Table 106). With restructured steaks from round muscles, pressurization caused a more rare degree of doneness, but a longer cooking time. The opposite situations were found for restructured steaks manufactured from chuck muscles. In terms of cooking loss (Table 107), the values were affected by a three-way interaction. In this interaction, pressurization resulted in lower cooking losses in all comparisons except in nonvacuum packaged chuck muscle. Likewise, nonpressurized-nonvacuum

Table 101. Interaction effects of raw material source, pressurization and packaging system on texture profile panel scores for macro and micro distortion.

Raw material source	Pressurization	Packaging system	Macro distortion[a]	Micro distortion[a]
Round	Pressurized	Vacuum	4.5 ± 1.0	4.4 ± 1.2
Round	Pressurized	Non vacuum	5.0 ± 0.8	4.9 ± 1.2
Round	Not pressurized	Vacuum	5.3 ± 1.1	4.2 ± 1.4
Round	Not pressurized	Non vacuum	3.9 ± 0.8	3.8 ± 0.6
Chuck	Pressurized	Vacuum	4.1 ± 0.6	4.2 ± 0.9
Chuck	Pressurized	Non vacuum	5.3 ± 1.1	4.8 ± 0.9
Chuck	Not pressurized	Vacuum	2.8 ± 1.3	3.2 ± 0.9
Chuck	Not pressurized	Non vacuum	4.9 ± 1.2	4.9 ± 1.6

[a]Definitions for macro and micro distortion are given in Appendix Table 4.

Table 102. Frequency of fragmentation categories in restructured beef steaks according to the use of pre-rigor pressurization.

Fragmentation category[a]	Pressurized	Not pressurized
Complete shearing	6.4	5.0
Incomplete shearing--threads	19.3	18.6
Incomplete shearing--crust	3.6	5.0
Complete crumbly separation	0.7	0.0
Incomplete crumbly separation--threads	0.7	0.0
Incomplete crumbly separation--crust	0.0	0.7
Compacts along shear line	4.3	3.6
Chunky and complete separation	2.1	2.8
Incomplete chunky separation--threads	8.6	10.7
Incomplete chunky separation--crust	4.3	3.6
Layered separation	0.0	0.0
Other	0.0	0.0

[a]Values are percentage frequencies of sample evaluations for pre-rigor presssurization that were classified into the fragmentation categories.

Table 103. Frequency of fragmentation categories in restructured beef steaks according to source of raw material.

Fragmentation category[a]	Raw material Round	Chuck
Complete shearing	1.5	10.0
Incomplete shearing--threads	6.4	31.4
Incomplete shearing--crust	4.3	4.3
Complete crumbly separation	0.0	0.0
Incomplete crumbly separation--threads	0.7	0.7
Incomplete crumbly separation--crust	0.7	0.0
Compacts along shear line	5.0	2.8
Chunky and complete separation	3.6	1.4
Incomplete chunky separation--threads	12.8	6.4
Incomplete chunky separation--crust	5.7	2.1
Layered separation	0.0	0.0
Other	0.0	0.0

[a]Values are percentage frequencies of sample evaluations for both sources of raw material combined that were classified into the fragmentation categories.

Table 104. Effects of raw material source on Instron values of restructured beef steaks.

	Raw material source	
Instron value	Round	Chuck
Maximum shear force, kg	24.8 + 3.5[a]	21.6 + 2.9[b]
Newtons/cm^2	29.3 + 4.3[a]	25.5 + 3.8[b]

[a,b]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 105. Effect of pre-rigor pressurization on change in steak width during cooking of restructured beef steaks.

Pressurization	Change in steak width from raw to cooked, location 1, %
Pressurized	-2.1 ± 5.4^{b}
Not pressurized	3.1 ± 6.4^{a}

Table 106. Interaction effects of raw material source and pre-rigor pressurization on cooking properties of restructured beef steaks.

Raw material source	Pressurization	Cooking property: Degree of doneness score	Cooking property: Cooking time, min/g
Round	Pressurized	2.8 ± 0.5	0.18 ± .005
Round	Not pressurized	2.4 ± 0.5	0.17 ± .011
Chuck	Pressurized	2.2 ± 0.5	0.15 ± .002
Chuck	Not pressurized	3.0 ± 0.8	0.17 ± .022

Table 107. Interaction effects of raw material source, pre-rigor pressurization and packaging system on cooking loss of restructured beef steaks.

Raw material source	Pressurization	Packaging system	Cooking loss, %
Round	Pressurized	Vacuum	28.5 ± 1.8
Round	Pressurized	Non vacuum	27.6 ± 2.5
Round	Not pressurized	Vacuum	30.0 ± 2.2
Round	Not pressurized	Non vacuum	30.8 ± 2.2
Chuck	Pressurized	Vacuum	27.3 ± 2.5
Chuck	Pressurized	Non vacuum	27.6 ± 2.1
Chuck	Not pressurized	Vacuum	28.0 ± 2.4
Chuck	Not pressurized	Non vacuum	24.4 ± 1.7

[a]Definition for the various characteristic are given in Appendix Table 4.

packaged chuck steaks had lower cooking losses than nonpressurized-vacuum packaged chuck steaks. Other comparisons for cooking loss between the two packaging systems failed to produce any differences.

The next series of tables compares product type, salt levels and packaging systems. Considerable differences in texture profile panel characteristics were detected between flaked and formed and chunked and formed steaks (Table 108). Chunked and formed steaks were rated as being more fibrous than flaked and formed steaks. This would be expected. Springiness was also higher in chunked and formed steaks. Under first bite characteristics, greater hardness and cohesiveness, but less uniformity was noted in chunked and formed vs flaked and formed steaks. The significant differences in mastication properties between the two product types generally reflect the larger size meat particles in the chunked and formed product.

There was a higher incidence of incomplete shearing, incomplete crumbly separation and compacting along shear line for flaked and formed steaks vs chunked and formed steaks (Table 109). Chunked and formed steaks were characterized as having more incomplete chunky separation with threads. The effects of salt level on fragmentation frequencies is presented in Table 110. There were surprisingly very few differences. Most of the categories checked regardless of salt level were in the incomplete chunky separation - threads. The effects of vacuum vs nonvacuum packaging are presetned in Table 111. In both studies, nonvacuum packaging resulted in more incomplete shearing with threads compared to vacuum packaging.

The interaction effects of product type, packaging system and salt level on texture profile panel scores for macro distortion in restructured

Table 108. Effects of product type on texture profile panel scores for restructured beef steaks.

Characteristic[a]	Product type: Flaked and formed	Product type: Chunked and formed
Visual		
Fibrousness	5.9 ± 1.7^c	8.3 ± 1.8^b
Partial compression		
Springiness	8.1 ± 2.6^c	9.2 ± 2.1^b
First bite		
Hardness	7.9 ± 1.7^c	9.2 ± 1.8^b
Cohesiveness	9.0 ± 1.9^c	10.1 ± 1.4^b
Uniformity	10.4 ± 1.6^b	9.8 ± 2.0^c
Moisture release	4.5 ± 0.9	4.8 ± 0.7
Mastication		
Juiciness	5.8 ± 1.0	6.2 ± 0.9
Size of chewed particles	9.0 ± 1.4^c	9.8 ± 1.3^b
Cohesiveness of mass	9.4 ± 2.0^c	10.6 ± 1.4^b
Gristle	1.7 ± 1.7^c	2.7 ± 1.8^b
Webbed tissue	4.0 ± 1.2	4.2 ± 1.6
Overall gristle	1.8 ± 2.0^c	2.9 ± 1.8^b
Overall webbed tissue	3.7 ± 1.0	4.1 ± 1.6
Number of chews	52.8 ± 10.8^c	63.1 ± 6.9^b
After swallow		
Tooth pack	3.1 ± 0.8	2.8 ± 0.8
Mouth coating	4.3 ± 1.2	4.0 ± 1.4

[a]Definitions for the various characteristics are given in Appendix Table 4.

[b,c]Means in the same row bearing different superscripts are significantly ($P < 0.05$) different.

Table 109. Frequency of fragmentation categories in restructured beef steaks according to product type.

Fragmentation category[a]	Product type: Flaked and formed	Product type: Chunked and formed
Complete shearing	2.9	0.5
Incomplete shearing--threads	12.0	5.7
Incomplete shearing--crust	1.0	0.5
Complete crumbly separation	3.4	0.0
Incomplete crumbly separation--threads	12.0	0.5
Incomplete crumbly separation--crust	0.5	0.0
Compacts along shear line	11.0	2.4
Chunky and complete separation	2.9	1.4
Incomplete chunky separation--threads	10.0	19.6
Incomplete chunky separation--crust	1.0	3.8
Layered separation	1.9	0.5
Other	1.9	4.8

[a]Values are percentage frequencies of sample evaluations for both product types combined that were classified into the fragmentation categories.

Table 110. Frequency of fragmentation categories in restructured beef steaks according to salt level.

	Salt level, %		
Fragmentation category[a]	0.00	0.25	0.50
Complete shearing	1.9	1.4	0.0
Incomplete shearing--threads	4.8	4.3	8.6
Incomplete shearing--crust	0.5	0.5	0.5
Complete crumbly separation	1.4	1.0	1.0
Incomplete crumbly separation--threads	3.8	4.8	3.8
Incomplete crumbly separation--crust	0.0	0.0	0.5
Compacts along shear line	5.7	4.8	2.9
Chunky and complete separation	1.4	1.0	1.9
Incomplete chunky separation--threads	10.5	10.0	9.1
Incomplete chunky separation--crust	1.0	1.4	2.4
Layered separation	0.5	1.4	0.5
Other	1.4	1.9	3.3

[a]Values are percentage frequencies of sample evaluations within salt levels that were classified into the fragmentation categories.

Table 111. Frequency of fragmentation categories in restructured beef steaks according to packaging system.

	From product type, salt level study		From source of raw material, pressurization study	
Fragmentation category[a]	Vacuum	Non-vacuum	Vacuum	Non-vacuum
Complete shearing	1.0	2.4	5.7	5.7
Incomplete shearing--threads	6.7	11.0	12.9	25.0
Incomplete shearing--crust	1.0	0.5	2.9	5.7
Complete crumbly separation	2.4	1.0	0.7	0.0
Incomplete crumbly separation--threads	6.2	6.2	0.0	0.7
Incomplete crumbly separation--crust	0.5	0.0	0.0	0.7
Compacts along shear line	4.3	9.1	4.3	3.6
Chunky and complete separation	1.9	2.4	2.1	2.9
Incomplete chunky separation--threads	15.8	13.9	10.0	9.3
Incomplete chunky separation--crust	2.4	2.4	4.3	3.6
Layered separation	1.9	0.5	0.0	0.0
Other	3.8	2.9	0.0	0.0

[a]Values are percentage frequencies of sample evaluations for both packaging systems within a study combined that were classified into the fragmentation categories.

beef steaks are provided in Table 112. It is difficult to pick out any logical trends. More macro distortion was observed in nonvacuum packaged steak processed with 0.50% salt regardless of product type. It was expected that lower levels of salt perhaps might result in less extraction of protein with the possibilities of less crust formation and hopefully less distortion. No differences were noted between vacuum and nonvacuum packaging for micro distortion of flaked and formed steaks, while nonvacuum packaging caused a slight increase in the presence of micro distortion in chunked and formed product (Table 113). Packaging did not seem to affect micro distortion of flaked and formed steaks. Uniformity of the mass was evaluated as being higher in nonvacuum packaged flaked and formed steaks in contrast to vacuum packaged flaked and formed steaks. No differences were detected between packaging systems for chunked and formed steaks.

Increased salt levels (0.50%) produced higher Instron maximum shear and Newton values in chunked and formed product, but resulted in a slight decrease in flaked and formed steaks (Table 114). Salt levels themselves exerted no effect on texture profile panel results. Furumoto and Stadelman (1980) found with both hot and cold boned beef used in beef rolls a decrease in Instron shear values as salt usage dropped from 1.5 to 0.0%. In our study, 0.50% salt usage created a more well done cooked appearance and more shrinkage in steak width than 0.00% salt usage (Table 115). Chunked and formed steaks underwent substantially more reduction in steak thickness during cooking than steaks made by the flaking and forming process (Table 116). Actually the flaked and formed steaks made with 0.50% salt had an increase in steak thickness during cooking. At the 0.25% salt level, flaked and formed steaks had less cooking time to 70° C

Table 112. Interaction effects of product type, packaging system and salt level on texture profile panel scores for macro distortion in restructured beef steaks.

Product type	Packaging system	Salt level, %	Macro distortion[a]
Flaked and formed	Vacuum	0.0	5.2 ± 1.2
Flaked and formed	Vacuum	0.25	5.8 ± 1.7
Flaked and formed	Vacuum	0.50	4.2 ± 1.3
Flaked and formed	Non vacuum	0.0	4.0 ± 1.1
Flaked and formed	Non vacuum	0.25	4.3 ± 0.6
Flaked and formed	Non vacuum	0.50	5.9 ± 1.0
Chunked and formed	Vacuum	0.0	6.2 ± 1.6
Chunked and formed	Vacuum	0.25	4.3 ± 1.0
Chunked and formed	Vacuum	0.50	4.2 ± 1.3
Chunked and formed	Non vacuum	0.0	5.7 ± 1.6
Chunked and formed	Non vacuum	0.25	6.3 ± 2.2
Chunked and formed	Non vacuum	0.50	7.2 ± 1.6

[a]Definition for macro distortion given in Appendix Table 4.

Table 113. Interaction effects of product type and packaging system on texture profile panel scores for restructured beef steaks.

		Characteristic[a]	
Product type	Packaging	Micro distortion	Uniformity of mass
Flaked and formed	Vacuum	4.8 $\pm$ 1.2	10.7 $\pm$ 2.0
Flaked and formed	Non vacuum	4.7 $\pm$ 1.0	11.6 $\pm$ 1.0
Chunked and formed	Vacuum	5.6 $\pm$ 1.9	10.4 $\pm$ 1.7
Chunked and formed	Non vacuum	6.6 $\pm$ 2.4	10.2 $\pm$ 1.3

[a]Definition for the various characteristic are given in Appendix Table 4.

Table 114. Interaction effect of product type and salt level on Instron values of restructured beef steaks.

		Instron value	
Product type	Salt level, %	Maximum shear force, kg	Newtons/cm^2
Flaked and formed	0.00	27.5 $\pm$ 6.3	32.5 $\pm$ 8.1
Flaked and formed	0.25	24.7 $\pm$ 6.4	29.7 $\pm$ 8.1
Flaked and formed	0.50	24.3 $\pm$ 4.7	25.6 $\pm$ 5.1
Chunked and formed	0.00	27.3 $\pm$ 6.7	36.8 $\pm$ 10.9
Chunked and formed	0.25	26.3 $\pm$ 6.5	34.7 $\pm$ 8.9
Chunked and formed	0.50	34.1 $\pm$ 9.4	42.2 $\pm$ 13.3

Table 115. Effects of salt level on cooking properties of restructured beef steaks.

	Cooking property	
Salt level, %	Degree of doneness score	Change in steak width-location 1, %
0.00	3.2 ± 0.7^{a}	1.7 ± 5.6^{b}
0.25	2.8 ± 0.6^{ab}	-4.8 ± 5.7^{a}
0.50	2.5 ± 0.4^{b}	-8.1 ± 7.3^{a}

[a,b]Means in the same line bearing different superscripts are significantly ($P < 0.05$) different.

Table 116. Interaction effect of product type with salt level on cooking properties of restructured beef steaks.

		Cooking properties		
Product type	Salt level	Change in steak thickness from raw to cooked, %	Cooking time, min/g	Change in steak length from raw to cooked, %
Flaked and formed	0.00	- 8.4 ± 3.3	0.19 ± .009	-22.6 ± 3.0
Flaked and formed	0.25	-10.6 ± 5.0	0.17 ± .006	-19.4 ± 3.1
Flaked and formed	0.50	+ 8.4 ± 8.7	0.18 ± .014	-25.2 ± 2.7
Chunked and formed	0.00	-17.7 ± 7.4	0.18 ± .021	-22.2 ± 3.6
Chunked and formed	0.25	-17.2 ± 5.4	0.19 ± .012	-24.2 ± 5.0
Chunked and formed	0.50	-15.8 ± 4.6	0.18 ± .008	-21.6 ± 2.4

and less reduction in steak length than their chunked and formed counterparts.

Vacuum packaged, flaked and formed steaks had less well done cooked appearance than nonvacuum packaged flaked and formed steaks (Table 117). The opposite situation was true for chunked and formed steaks. At the 0.0 and 0.25% salt levels, vacuum packaged steaks had slightly higher cooking losses than nonvacuum packaged steaks (Table 118). The opposite situation occurred for steaks formulated with 0.50% salt.

Conclusions

Prerigor pressurization does not appear to offer any major benefits in the manufacture of restructured beef steaks. However, this process does not appear to impose any major detrimental factors either. Since pressurization was unique to just the prerigor beef, it cannot be ascertained from this study whether hot boning per se has no detrimental effects for restructured beef steaks. Steaks manufactured from round muscles seem to impart less uniformity in texture, more connective tissue, less complete shearing and more shear force than steaks processed from chuck muscles. In most cases, steaks stored briefly in vacuum packaging seemed to have, in most cases, less distortion in the cooked steaks than was the situation for steaks stored in nonvacuum packaging. In contrast to flaked and formed steaks, chunked and formed steaks were rated as harder, more cohesive, less uniform and possessive of more connective tissue by the texture panel. Increased salt usage produced substantially higher Instron values in chunked and formed steaks.

Table 117. Interaction effects of product type and packaging system on scores for degree of doneness in restructured beef steaks.

Product type	Packaging system	Degree of doneness score
Flaked and formed	Vacuum	3.4 ± 0.5
Flaked and formed	Non vacuum	3.1 ± 0.2
Chunked and formed	Vacuum	3.0 ± 0.0
Chunked and formed	Non vacuum	3.3 ± 0.6

Table 118. Interaction effects of salt level and packaging system on cooking loss in restructured beef steaks.

Salt level, %	Packaging system	Cooking loss, %
0.0	Vacuum	33.5 ± 2.7
0.0	Non vacuum	34.0 ± 2.0
0.25	Vacuum	33.3 ± 2.2
0.25	Non vacuum	32.9 ± 2.1
0.50	Vacuum	31.1 ± 2.7
0.50	Non vacuum	33.0 ± 2.4

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Appendix Table 1. Restructured steak profile panel procedures and terms, early studies.

Description of Breakdown:

Sample steak patty should be visually evaluated for:

Distortion: The degree to which overall sample has warped.

Smoothness: The degree to which surface appears even.

Steak patty is then cut in half (if separate steak is unavailable) and cross section visually evaluated for:

Fibrousness: Degree to which sample resembles steak. (Lack of disruption of components.)

Partial Compression: Place warm 1" square in mouth, and using molars against cooked surfaces compress 1/3 distance and release. Count to 5 and evaluate for:

Hardness: Amount of force required to bite through sample.

Cohesiveness: Degree to which sample deforms before shearing.

Moisture Release: Amount of juiciness.

Uniformity: Degree to which force needed to shear sample is same across bite area.

Chew Down: Take warm sample, 1" cut align as per partial compression for first chew, turn 90° and realign as before for second chew and evaluate for:

Chunkiness: (2 chews) Degree to which sample breaks into chunks.

Juiciness: (10 chews) Amount of moisture released.

Procedure: Move bulk of mass to center of mouth, using tongue as feeler and evaluate for:

Cohesiveness of Mass: (15 chews) Degree to which particles stick together.

Coarseness of Mass: (15 chews) Degree to which irregular shaped particles can be detected. (Whether free floating or connected, absence of smoothness, i.e., lack of slickness makes mass seem perceptibly coarser.)

Appendix Table 1. Continued

<u>Cohesiveness of Mass</u>: (25 chews) Degree to which particles stick together.

<u>Coarseness of Mass</u>: (25 chews) Degree to which irregular shaped particles can be detected. (Whether free floating or connected, absence of smoothness, i.e., lack of slickness makes mass seem perceptibly coarser.)

<u>Uniformity of Mass</u>: (25 chews) Degree to which components of the mass are the same.

<u>Connective Tissue</u>:

A. Gristle: (25 chews) Amount of rubbery particles present.

B. Webbed tissue: Amount present just before swallowing.

<u>Chewiness</u>: Number of chews.

After Swallow: evaluate for:

<u>Particles</u>: Amount of loose material remaining after swallow. (3-5 = low); (6-10 = med.); (11-15 = high).

<u>Tooth Pack</u>: Amount of sample remaining in between teeth.

<u>Mouth Coating</u>: Amount of film (not taste) left on mouth surface.

Appendix Table 2. Restructured steak profile panel procedures and terms, early-intermediate studies.

Description of Breakdown (Pay particular attention to the number of chews at which sample has maximum cohesiveness:

Sample steak patty should be visually evaluated for:

Distortion: The degree to which overall sample has warped.

Steak patty is then cut in half (if separate steak is unavailable) and cross section visually evaluated for:

Fibrousness: Degree to which sample resembles steak. (Lack of disruption of components.)

Partial Compression: Place warm 1" square in mouth, and using molars against cooked surfaces, press lightly 4-5 times, wait a count of 2 for each press and evaluate for:

Springiness: The perceived degree and speed with which sample returns to original height and thickness.

First Bite: Take fresh 1" square, place in mouth as for partial compression and evaluate for:

Hardness: Amount of force required to bite through sample.

Cohesiveness: Degree to which sample deforms before shearing.

Moisture Release: Amount of juiciness.

Uniformity: Degree to which force needed to shear sample is same across bite area.

Chew Down: Take warm sample, 1" cut align as per partial compression for first chew, turn 90° and realign as before for second chew and evaluate for:

Fragmentation: (2 chews) Check the appropriate box, giving additional information that seems important.

Juiciness: (7 chews) Amount of moisture released.

Appendix Table 2. Continued

Procedure: Move bulk of mass to center of mouth, using tongue as feeler and evaluate for:

Size of Chewed Pieces: (10 chews) The perceived size of clearly separate pieces or pieces held together only by connective tissue web.

Gristle: (10 chews) Amount of rubbery particles present.

Cohesiveness of Mass: (10 and 25 chews) Degree to which particles stick together.

Uniformity of Mass: (25 chews) Degree to which components of the mass are the same.

Webbed Connective Tissue: Amount present just before swallowing.

Chewiness: Number of chews.

After swallow evaluate for:

Tooth Pack: Amount of sample remaining in between teeth.

Mouth Coating: Amount of film (not taste) left on mouth surface.

Chew Down:

Fragmentation (2 chews):

Shears cleanly	[ ]
Crumbly separation	[ ]
Compacts along shear line	[ ]
Chunky Separation	
Complete	[ ]
Incomplete	[ ]
Layered Separation	[ ]
Other	[ ]
Describe:	

Appendix Table 3. Restructured steak profile panel procedures and terms, intermediate-late studies.

Description of Breakdown (Pay particular attention to the number of chews at which sample has maximum cohesiveness):

Sample steak patty should be visually evaluated for:

Distortion:

Macro--The degree to which overall sample is uneven or warped (as viewed through a frosted glass).

Micro--The degree to which cooked surfaces look uneven or rough.

Fibrousness: Degree to which sample resembles steak. (Lack of disruption of components.)

Partial Compression: Place warm 1" square in mouth, and using molars against cooked surfaces, press lightly 4-5 times, wait a count of 2 for each press and evaluate for:

Springiness: The perceived degree and speed with which sample returns to original height and thickness.

First Bite: Take fresh 1" square, place in mouth as for partial compression and evaluate for:

Hardness: Amount of force required to bite through sample.

Cohesiveness: Degree to which sample deforms before shearing.

Moisture Release: Amount of juiciness.

Uniformity: Degree to which force needed to shear sample is same across bite area.

Chew Down: Take warm sample, 1" cut align as per partial compression for first chew, turn 90° and realign as before for second chew and evaluate for:

Fragmentation: (2 chews) Check the appropriate box, giving additional information that seems important.

Juiciness: (7 chews) Amount of moisture released.

Appendix Table 3. Continued

Procedure: Move bulk of mass to center of mouth, using tongue as feeler and evaluate for:

Size of Chewed Pieces: (10 chews) The perceived size of clearly separate pieces or pieces held together only by connective tissue web.

Gristle: (10 chews) Amount of rubbery particles present.

Cohesiveness of Mass: (10-35 chews) Degree to which particles stick together. (Rate when sample is at its maximum and give the chew count at which it was rated).

Uniformity of Mass: (25 chews) Degree to which components of the mass are the same.

Webbed Connective Tissue: Amount present just before swallowing.

Chewiness: Number of chews.

After swallow evaluate for:

Tooth Pack: Amount of sample remaining in between teeth.

Mouth Coating: Amount of film (not taste) left on mouth surface.

Chew Down:

Fragmentation (2 chews):

	A	B	
Shears cleanly--complete	[ ]	[ ]	1
Incomplete--threads	[ ]	[ ]	2
Incomplete--crust	[ ]	[ ]	3
Crumbly separation			
Complete	[ ]	[ ]	4
Incomplete--threads	[ ]	[ ]	5
Incomplete--crust	[ ]	[ ]	6
Compacts along shear line	[ ]	[ ]	7
Chunky Separation			
Complete	[ ]	[ ]	8
Incomplete--threads	[ ]	[ ]	9
Incomplete--crust	[ ]	[ ]	10
Layered Separation	[ ]	[ ]	11
Other	[ ]	[ ]	12

Describe:

Appendix Table 4. Restructured steak profile panel procedures and terms, late studies.

Description of Breakdown (Pay particular attention to the number of chews at which sample has maximum cohesiveness):

Sample steak patty should be visually evaluated for:

Distortion:

Macro--The degree to which overall sample is uneven or warped (as viewed through a frosted glass).

Micro--The degree to which cooked surfaces look uneven or rough.

Fibrousness: Degree to which sample resembles steak. (Lack of disruption of components.)

Partial Compression: Place warm 1" square in mouth, and using molars against cooked surfaces, press lightly 4-5 times, wait a count of 2 for each press and evaluate for:

Springiness: The perceived degree and speed with which sample returns to original height and thickness.

First Bite: Take fresh 1" square, place in mouth as for partial compression and evaluate for:

Hardness: Amount of force required to bite through sample.

Cohesiveness: Degree to which sample deforms before shearing.

Moisture Release: Amount of juiciness.

Uniformity: Degree to which force needed to shear sample is same across bite area.

Chew Down: Take warm sample, 1" cut align as per partial compression for first chew, turn 90° and realign as before for second chew and evaluate for:

Fragmentation: (2 chews) Check the appropriate box, giving additional information that seems important.

Juiciness: (7 chews) Amount of moisture released.

Appendix Table 4. Continued

Procedure: Move bulk of mass to center of mouth, using tongue as feeler and evaluate for:

Size of Chewed Pieces: (10 chews) The perceived size of clearly separate pieces or pieces held together only by connective tissue web.

Gristle: (10 chews) Amount of rubbery particles present.

Cohesiveness of Mass: (10-35 chews) Degree to which particles stick together. (Rate when sample is at its maximum and give the chew count at which it was rated).

Uniformity of Mass: (25 chews) Degree to which components of the mass are the same.

Webbed Connective Tissue: Amount present just before swallowing.

Chewiness: Number of chews.

After swallow evaluate for:

Tooth Pack: Amount of sample remaining in between teeth.

Mouth Coating: Amount of film (not taste) left on mouth surface.

Overall:

Gristle: (overall impression) Amount of rubbery particles present.

Webbed Connective Tissue: (overall impression) Amount of firm thread-like connective tissue present.